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METALLURGIA

THE BRITISH JOURNAL OF METALS

METALLURGIA

The British Journal of Metals

(INCORPORATING THE METALLURGICAL ENGINEER)

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METALLURGIA

THE BRITISH JOURNAL OF METALS.

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Export Targets for 1948

THE progressive spirit which is now permeating British trade and industry is reflected in the gradual increase in production. Considerable strides have been made in developing greater efficiency and manufacturers can take credit for contributing towards the expansion of export trade now being experienced. For some time after the war there did not seem to be the incentive to apply the same degree of skill, energy and determination in industry as under war conditions. Probably this was due to reaction following the strenuous war years, which caused a certain laxity of purpose industrially. In addition, of course, the conclusion of hostilities brought this country every possible major political, economic and social problem, many of which still remain unsolved. It is, however, the economic aspect with which industry is primarily concerned, and from production returns it would seem that managements and men are getting into their stride again and doing much to effect equilibrium between exports and imports, but equilibrium is not yet in sight and a hard road has yet to be travelled before this can be achieved.

In his economic survey in September last, Sir Stafford Cripps stressed the need for greater productivity to raise the volume and value of exports in order to balance our overseas payments as rapidly as possible. The unbalance of the country's dollar account was, of course, the most obvious and critical, and still is, although we are getting further temporary assistance from the United States under the Marshall Plan. But Sir Stafford considered that Britain should balance her own accounts and proposed a scheme to increase exports by £31 million a month. To achieve this precise figures were given, industry by industry, of the percentage expansion required. These targets provided industry with definite objectives and in all represented an expansion in volume of British 1938 exports of 160%. This was a formidable task and it has become apparent that all these targets could not be achieved, and revised export targets for the end of 1948 have recently been proposed by Sir Stafford.

The most important reason for the change from the September targets is that considerably less steel will be available for use in the engineering industries than would be required to meet the original targets, some of which were found to be unrealistic in the light of steel supplies likely to be available in 1948. This shortage has made it necessary for many of the targets in the machinery and vehicle groups to be reduced. The new targets have been prepared by the Ministry of Supply in the light of their knowledge of the steel supplies available and their estimate of the proportion of output that will be available for export. They will be discussed with the particular industry and, if necessary, the figures will be adjusted.

It seems apparent that the original target figures were over optimistic, especially since the production of steel has consistently exceeded the production planned. Indeed, it is doubtful whether any other industry has risen so admirably as the iron and steel industry to the pressing needs of the country. The five year plan on which this industry is developing is a capacity of 16 million tons per annum and a target of 14 million tons was set for this year. So well has the industry been working that production so far this year approaches very nearly a rate of 15 million tons per annum. There would seem to be no doubt that the engineering industries could now use the maximum from the 16 million tons capacity planned for 1952, however, since the target figures for this year are based on 14 million tons production, any increase on this figure will involve target adjustments, and there is evidence that a substantial increase can be achieved providing ample iron and scrap are available.

Should adjustments be possible as a result of increased availability of steel it is to be hoped that the shipbuilding industry will be given at least a reasonable quota. Ships and machinery are vital to the return to prosperity. We need ships to make good war-time losses. We need in these ships all the latest ideas that make for efficient running, they will reduce freight charges and attract business. In addition to carrying our own cargoes, we would then be in a better position to carry foreign cargoes and provide badly needed revenue. We need ships to take the place of the United States ships chartered in this country and now being recalled to operate by the United States under the Marshall Plan. This may well become a drain on the dollar resources we receive. And, it will be remembered, Sir Stafford, in his economic survey in September, made it clear that we did not wish to be tied by economic strings to the political policies of other countries, however friendly they may be.

In recent months some industries have been hampered in their efforts to export by the imposition of export restrictions by overseas countries. Fortunately the Government has taken action on this question and the position has recently improved as a result of the conclusion of a number of commercial agreements with many countries concerned. In some cases the saturation of overseas markets will prevent them from absorbing the full quantity of products envisaged in the targets and considerable care will be necessary to prevent products piling up and involving long storage. There is need for a reasonable degree of flexibility of output to meet the needs of overseas markets. It is in this direction that the British Industries Fair will be helpful in bringing to the notice of overseas visitors the remarkable range of United Kingdom products.

Apart from limitations imposed on production by shortages of steel the revised export targets indicate that markets are hardening and, while the working spirit

in this country has greatly improved in the past year or so, it will continue to be a stern struggle to manufacture and sell overseas the products necessary to achieve the figures given. There are many advantages in large scale planned production, providing it is sufficiently flexible to meet the needs of the market sought, but there are also disadvantages, an important one being obtaining licences for, and subsequently delivery of, materials involved. The operation of all control systems must be delegated to people with varying degrees of ability and foresight—all possessed of human weaknesses—and lack of interest is frequently shown that interferes with the smooth working of the system, causing delays and sometimes a sense of frustration. Increased productivity can and should produce a state of mind to which all can adapt themselves in serving the national interest. When this feeling is more widespread target figures will more easily be achieved.

British Gas Turbines

THE most outstanding phase of British engineering progress is undoubtedly the successful development of the internal combustion turbine. Initially developed for aircraft the progress achieved owes much to the pioneer work of Air Commodore Frank Whittle, C.B.E. and to the early labours of A. A. Griffith and Hayne Constant, but during the last six or seven years remarkable advances have been made by many British firms who are actively developing gas turbines of various kinds. It should not be forgotten, however, that a great deal of original research, vital to the rapid rate of progress, has been conducted at the Government-owned National Gas Turbine Establishment, generally known as Power Jets (Research & Development), Ltd. Some idea was given of the effects of British achievements in this field at a recent Conference organised by the Ministry of Supply in association with Power Jets.

There seems no doubt that the gas turbine will prove to be the cheapest form of industrial power yet known. As Mr. W. E. P. Johnson, Executive Director of Power Jets (Research & Development), Ltd., pointed out, the gas turbine, as an engine, is unique in two ways. First, because it is a heat engine in which the three essential functions in a heat engine—those of compression, heating and expansion—are analysed out into three organic units. Second, because it is the most universally applicable form of prime mover yet devised. In relation to its peculiar three-functional analysis, whilst this may not be at first sight a very spectacular attribute it must be remembered that any improvements introduced in any one of the three fundamental organs become available to other industrial products involving such organs. For example, an advance in compressors becomes available not only to gas turbines but to compressors as such, for whatever purpose a compressor may be required. Thus the technology of gas turbines is extremely catholic and should be of the greatest interest to specialists in compressors, and the same view applies to the combustion of fuel, turbines, heat exchangers, metallurgy and so forth. It follows that almost no engineer can afford to ignore the gas turbine as a compendium of technology.

With the advent of the gas turbine, a prime mover is in sight, applicable from high-speed aircraft to electrical generation, and from blast furnaces to gas liquefaction. The subsidiary type of utilisation, such as that of district heating in conjunction with power generation is not unimportant. Electrical generation, especially for peak load purposes, is an accepted use. The possible contribution of the gas turbine to naval power has already received some notice. Its light and compact construction and its ability to develop full power in a very short time, are among its naval claims. For fast passenger ships a good case can be made out.

There is scarcely any phase of British industry which will not, in time, be affected by the gas turbine. The gas turbine locomotive, for instance, is an accepted competitor of the Diesel type. Mr. Johnson stated that a coal burning locomotive should be able to run at an operating cost of approximately half that of the present steam job, and about 40% less than that of a diesel, the basis of comparison being cost per 1,000 rail h.p. hours. It is noteworthy that two experimental gas-turbine locomotives are already on order for British Railways. There are propitious signs that it may soon be applied to high-powered lorries and buses; however, the most important fields of development for this type of engine are in fast passenger ships and in the big national and municipal plants.

A considerable part of work of the Power Jet Company, at the moment, is concerned with less well explored fields of gas turbine application. At the Birmingham section of the British Industries Fair the Company is showing two models which demonstrate the application of a gas turbine to the highly important manufacture of nitric acid with its consequent potential cheapening of fertilisers. These were selected as an example of the applicability of this type of machine in a process. There is a great number of other chemical processes to which the technology can apply: It is predicted that the production of cheap oxygen from which a whole revolution of industry may spring, will turn largely on the application of current gas-turbine research and development. Cheaper steel, cheaper coke, cheaper and more available fertiliser, cleaner industry, better transport, are all targets within the range of the gas turbine.

It is interesting to note the Metropolitan-Vickers Electrical Co., Ltd. exhibit at the B.I.F. a model of the 2,000 kW gas-turbine alternator that is being built for the Metrovick power station at Trafford Park. The plant will be the first of its kind in this country. This unit will have a thermal efficiency comparable with an efficient steam-power station of like capacity.

The efforts to secure widespread recognition of the outstanding technical and intellectual resources of this country in the gas-turbine field are marred by the fact that so few engines are available for show. This is inevitable since there must be a lapse of time between the appreciation of the fund of gas-turbine knowledge that was built up during the war, and its embodiment in machinery. But there is absolute confidence in the ultimate products, and in the meantime Power Jets is bridging the gap by the propagation of the knowledge incorporated in its patent holding, of which it controls some 2,000. These patents are operated firstly for the benefit of British industry and secondly with the object of earning foreign currency. Technology is the only export commodity which raises no tariff reprisals, and which establishes short-term profits as well as long-term benefits, but, in addition to revenue from licences granted to foreign firms, an immense export trade in completed engines should ultimately result.

Die-Casting Progress

Part IV—Pressure Die-Casting of Magnesium Alloys

By Dr. A. C. Street

With the need for increased production there is a natural desire to explore methods of production that are faster and cheaper than those normally used and for many purposes die castings are successfully meeting this need. In recent years this highly productive process has also been applied to magnesium alloys, and developments in pressure die-casting in this field are discussed.

THE casting of magnesium alloys into sand and permanent moulds is well established in this country and their availability in these forms is well understood. Pressure die casting of the same type of alloy is not of such long standing, and it is only in quite recent years that engineers and metallurgists have begun to appreciate that this highly productive process is applicable also to the so-called "ultra-light" alloys.

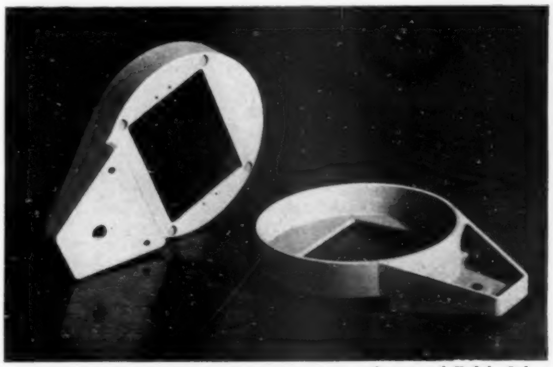
The substantial saving in weight made possible by the use of magnesium is often a decisive factor, particularly when it is coupled with appropriate design. The writer was interested in an example reported from America where an aircraft starter base was pressure die cast in magnesium alloy. Before die casting was used, this part was machined from a steel forging; the weight of the forging was 24·75 lb. and after machining, the weight of the finished article was 6·49 lb. Eventually this part was produced in magnesium; the weight of the die casting was only 1·74 lb., and after final machining was 1·62 lb.

The Germans were the pioneers of the technological applications of magnesium alloys, and it was in that country also that great developments took place in their pressure die casting. The leading specialists there were the firm of Mahle K.G., of Bad Cannstadt, of whom A. Bauer was the chief technician; they developed the process, using hot chamber machines exclusively, and it has been reported that they were able to make castings up to 12 lb. in weight at speeds of the order of 200 shots per hour. The largest dimensions for magnesium alloy pressure die castings which they reached were—length about 35 in., width about 32 in., depth about 12 in.

In the U.K. and the U.S., while it has been recognised that use of hot-chamber machines may be advantageous from many points of view, the cold-chamber type of machine has also been given extensive development, so much so that it is probably more used than the former.

The success of the cold-chamber machine depends even more than does that of the hot-chamber machine, on metallurgical skill as well as on good operation. The maximum size and weight of castings usually depend only on the dimensions of available machines.

The problems of pressure die-casting magnesium alloys are not essentially different from those involved in casting them by other processes; but when the technique of pressure die casting was being developed, certain difficulties were temporarily troublesome, though these have now been overcome in a satisfactory manner and die casters experienced in handling magnesium will nowadays comment that some parts can be pressure die cast more easily in magnesium than, for example, in aluminium alloys.



Courtesy of Kodak, Ltd.

Fig. 1.—Pressure die cast enlarger components in magnesium alloy.

Magnesium alloys are protected from oxidation in conventional melting procedure by the use of fluxes which consist essentially of mixed alkali and alkaline—earth chlorides and fluorides. These fluxes are normally sufficient to ensure effective elimination of oxide and nitride inclusions; however, residual flux inclusions are extremely harmful since the chlorides are deliquescent and lead to severe local corrosion. Flux inclusions were probably the most common defect of early pressure die castings in magnesium alloys; the necessity to avoid them provided the spur which lead to the development of special techniques or equipment.

In the sand casting of magnesium the low heat capacity of the alloys is an important factor, since it is in part responsible for the danger of microporosity. The solidification of the component occurs so quickly that mass feeding to compensate for local drainage of eutectic liquid may be prevented, unless special precautions are taken. In pressure die casting it also plays an important part; to reduce oxidation, the use of a low temperature is desirable, but the temperature cannot be too much reduced, or the heat capacity effect will be too adverse. In practice the metal temperature should be closely controlled, and the temperature of the die must be kept up, usually in the region of 250°–300° C. and sometimes higher.

Much research has been done on the magnesium pressure die-casting alloys and the one which was used in Germany, and which is most favoured in the U.K. and the U.S. is one containing 9% aluminium, about 0·5% zinc and about 0·25% manganese. This alloy is very suitable because of its good "flowing" properties; it is also quite good in resisting hot-cracking

tendencies, though there may be some room for improvement in the composition from this point of view. The more important general factor influencing hot cracking is the question of die design, which should be such as to help in reducing casting stresses. Not only is it necessary to apply the general principles of good design, such as the provision of large fillets, the rounding of corners and re-entrants, and smoothness in section changing, but special attention must be given to angles of taper or draft, a matter which will be touched upon later. Early ejection of the casting from the die is essential if cracks are to be avoided.

Hot Chamber Machine

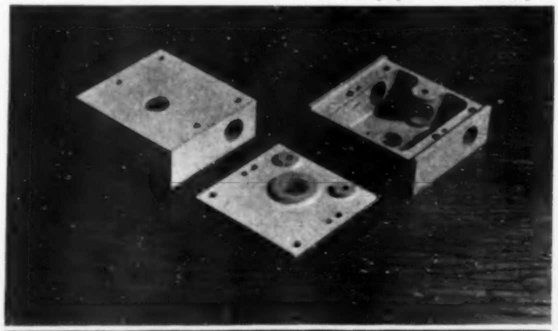
In Germany two kinds of hot-chamber machines were used;[1] the piston type was for the production of parts weighing up to about 1 lb., and the air-pressure type for larger pieces. The piston machine involves the use of two metal containers, one of which is a melting crucible. This is connected near its base by a heated tube (containing a valve) to the holding crucible, in which the metal is kept hot. The melting pot is maintained full of molten metal, so that contact with the air is avoided as far as metal passing into the holding crucible is concerned; there is, however, a very thin flux cover on the metal in the melting furnace. In the holding crucible the metal is protected by a heavy, tightly fitting cover; this crucible is kept nearly full by controlling the valve in the heated connecting tube, and as a result the air above the molten metal is soon depleted in oxygen and negligible oxidation of the surface occurs. Metal is taken from the holding crucible through a gooseneck to the die; a "shot" is forced along it by means of the operation of a steel piston which works in a pressure container located near the bottom of the crucible. The metal is injected at a pressure of 50–100 atmospheres, and the goose-neck tip is kept at a temperature of about 500° C. After each shot the metal drops back in the goose-neck to the level in the holding crucible. In order to ensure that the metal at the goose-neck tip remains molten, and that the casting itself solidifies quickly, the die is internally water-cooled in the region near the main gate, and the relative position of heated gooseneck tip and cooled gate is automatically controlled so that they are in contact only instantaneously when a shot is being made, at other times they are separated by a gap of 5 m.m.

The air-pressure machine is similar to the piston machine, except that it is larger, and the piston in the goose-neck is replaced by air pressure (sulphur dioxide is added to the air). The metal inlet is controlled by an automatically operated needle-valve; the air supply is at 30–80 atmospheres. This pressure is found to be quite high enough; the quality of magnesium alloy pressure die castings seems to be largely independent of the metal pressure. The air-pressure machine was not without its dangers, since if the needle valve failed to close properly, molten metal was blown out. To avoid injury to operators special interlocked safety booths were provided from which the machines were operated.

These machines have the advantages that they can be used with normal magnesium alloys and melting technique; they are designed so as to reduce to a negligible level the risk of oxidation, and the control of metal temperature is more precise than that prevailing with most cold-chamber machines. Their drawback is the obvious one that they are specialised, and only large orders can justify the capital expenditure they represent.

The latter factor has been predominant in the U.K. and U.S., and the tendency to use cold-chamber machines which could also be used for aluminium has no doubt been largely dictated by economic factors. The use of cold-chamber machines becomes technically much more acceptable if some method of avoiding the oxidation and flux-inclusion risks can be devised. It happens that additions of small quantities of beryllium (of the order of 0·005–0·01%) have a marked effect in reducing oxidation,[1, 2] although at the same time they tend to favour the production of a large grain size. In pressure die casting the effect of the turbulent entry of the metal into the mould and its subsequent rapid chilling is so pronounced that large grains are not formed, and the mechanical properties are not adversely affected; it is, therefore, possible to use beryllium to reduce the use of flux to vanishingly small quantities.

Fig. 2.—Aircraft door-lock parts in magnesium alloy.
Courtesy of Vickers Armstrong Ltd.



Courtesy of The De Havilland Aircraft, Co., Ltd.
Fig. 3.—Aircraft seat attachment brackets in magnesium alloy.

The German practice was to use tungsten steel for dies, containing 5–10% tungsten, 2·5% chromium and 0·3–0·4% vanadium, with a carbon content of about 0·25–0·35%. Great attention was paid to venting and gating practice in Germany, and this has been found to be necessary elsewhere. An excellent American review of this subject was published just over two years ago.[3] Here recommendations are made which are generally in line with German practice; for example a draft angle of 5° is recommended wherever possible, to obtain a smooth, crack-free surface; if this is not possible a reduction in the draft allowances can be made, but these must not fall below 1° for outside surfaces and 2° for inside surfaces which resist the free shrinkage of the casting.

1 Beck, A., "The Technology of Magnesium and its Alloys," London, 1940.

2 Burns, J. R., "Beryllium in Magnesium Casting Alloys," Amer. Soc. Metals, 1948–49, preprint 10.

3 Powell, M., and Scott, C. H., "Magnesium Die Castings," *Product Engineering*, 1947, Oct., p. 692.

Minimum wall thicknesses may be as low as $\frac{1}{32}$ in. for small parts having a maximum surface area of approximately 4 sq. in., and sections as heavy as $\frac{1}{2}$ in. can be pressure die cast. Holes should always be located in pads or bosses to distribute working stress as much as possible. Tolerances for magnesium pressure die castings[4] can be maintained at the same levels as for aluminium pressure die castings. Cast internal threads should be avoided.

Inserts of different materials can be cast in at places which support concentrated loads, or which are subject to heavy wear. Pins and the like should preferably extend right through the casting and permit positive location within the die cavity; if this cannot be arranged, they must be buried for a depth never less than that equal to one diameter, and preferably two. The inserts should be knurled on the buried portion to help ensure a good " lie " of the metal of the casting against them, and to ensure a good grip. The insert should be located at a place in the casting where the metal can be expected to shrink on to it and not away from it. For some applications it may be necessary to use cadmium or zinc-plated inserts, so as to minimise electrolytic action between the casting and the insert. However, this is necessary only when corrosion performance is likely to be a critical service factor. The provision of generous fillets and smoothness in section changes has already been mentioned as of great importance in preventing cracking; it is also often critical in ensuring good service performance.

Fig. 4.—Magnesium alloy bobbins used in textile machinery.

Magnesium alloy die castings made in the 9% aluminium alloy are severely segregated as cast, with heavy concentrations of aluminium in the extreme outer layers. This sometimes complicates the chemical dip treatments usually employed for magnesium alloys (described in D.T.D. specification 911A), and the films are sometimes rather blotchy. The castings do not, however, appear to suffer when painted, and the poor looking film seems to be none the less effective in performing its function as a paint base. However, there is room for development here, just as there is in the problem of anodising aluminium pressure die castings.

Before the war there were many successful applications of magnesium alloy pressure die castings for purposes such as binocular frames, typewriter frames, camera parts, etc. The German view was that at least 1,000 parts were to be required before pressure die casting could be considered; a recent American view[5] suggests that this figure may be reduceable to 500 in special circumstances. It is probable that in the U.K. a much higher minimum than the 1,000 would be set. Some cost data are available from large quantity production in Germany during the war, which suggest that on a weight basis of castings made, the labour cost for magnesium was about 20% higher than for aluminium pressure die castings; however, on a casting-for-casting basis (this takes into account the effect of the different densities) magnesium pressure die castings were 30% cheaper than those in aluminium. It may prove that these figures are not universally applicable outside war-time Germany.

There is considerable interest in the post-war uses of magnesium alloy pressure die castings, and in this country several pre-war applications have been taken up again. There seems neither technical nor economic reason why there should not be a wide expansion in this field in the next few years. The illustrations show four typical British applications of magnesium alloy pressure die castings.

One of the most well-known applications of magnesium alloy die casting is a hair dryer where light weight is of great importance. The die casting was previously produced in aluminium alloy, and, in the search for a still lighter product, magnesium alloy was used with little alteration to design. Another interesting example, was the steps of a ladder used for re-fuelling aircraft where the use of magnesium alloy pressure castings gave reduced weight and improved design.

In America much has been done in the use of magnesium for childrens' toys. For example, the Stearman Junior bicycle uses a magnesium die casting for the main frame, the fork and two smaller parts, thus constituting the major parts of a handsome machine.

Another interesting American application is in what we should call a child's push chair, but what the Americans more vividly call a " Strollmaster baby stroller." Magnesium was selected to give minimum weight and nine die castings were used. The rear support has overall dimensions about 15 × 15 in. and has an average wall thickness of 0·08 in. The seat back, complete with arms, is another large die casting on this " stroller," and contains an undercut portion.

Other die castings include the foot rest, handles and castors.

The writer is very grateful to Dr. F. A. Fox and to Messrs. Stone Fry Magnesium, Ltd., for help and advice during the preparation of this article.

Dr. Robert Charles Gooding Williams, M.I.E.E., M.I.Mech.E., chief engineer of Philips Electrical, Ltd., has been elected a Fellow of the American Institute of Electrical Engineers. He recently re-joined Philips Electrical, Ltd. (England) after a stay of just under two years with the North American Philips Company of New York, where he acted as an executive engineer.

4 " Elektron " Handbook, 1947, published by Messrs. F. A. Hughes & Co., London, p. 157.

5 du Mond, T. C., "Magnesium Alloys," *Materials and Methods*, 1947, May, p. 101.

Hydrogen, Nitrogen and Oxygen in Ferrous Metals

Their Properties and their Determination—Part VI

By E. C. Pigott

From the many independent researches conducted in many countries on the subject of gases in irons, steels and ferro-alloys, a very considerable amount of information has been amassed. The present series of articles reduces this mass of information to a succinct and co-ordinated form, presenting in clear perspective what has been regarded as an involved branch of metallurgy. In this, the concluding article, the author gives the actual procedure for operating each of the four recognised methods for determining oxygen.

Method 1.—Vacuum Fusion Method*

The furnace (Fig. 4) is of the carbon-spiral type, the spiral itself having eleven turns and being about 7 in. long and 2 in. in dia. Within the spiral a crucible of special design is supported on a small silica disc, which is sufficiently removed from the hot zone of the furnace not to react with the carbon with which it is in contact. The crucible is turned out in one piece from a graphite bar and is of the same length as the spiral, but the actual receptive portion of the crucible is only 4·5 in. long, the remaining 2·5 in. consisting of a thin supporting leg with a disc turned at its lower end to shield the silica support from direct radiation. At the upper end of the crucible a somewhat wider rim is left, the function of which is to prevent the crucible from leaning over and short-circuiting any of the turns of the spiral. Surrounding the spiral is a cylindrical molybdenum radiation screen, which rests upon the clamps for attaching and electrically connecting the lower end of the spiral to a mild-steel disc. These clamps are made of graphite and are screwed down with eight screws upon the flange at the lower end of the spiral. The top disc, attached to the spiral and to the top clamps, is also made of graphite and is supported on four mild-steel pillars which at their lower end screw into another mild-steel disc. Electrical connections are made to the upper and lower discs (Fig. 5).

The casing of the furnace is cooled by means of a water-jacket round the main body of the furnace, and by a hollow ring situated between the mild-steel discs and a hollowed-out lower plate upon which the crucible support rests. Damage to the furnace following possible failure of the main water supply is guarded against by the provision of an alternative supply operating in a closed circuit, and controlled by an entirely automatic pump.

* As operated by W. C. Newell; *Second Report of the Oxygen Sub-Committee.*

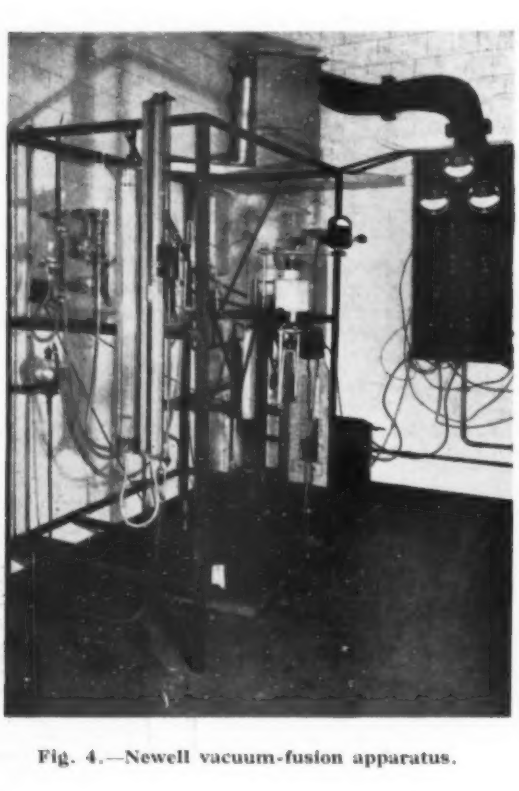


Fig. 4.—Newell vacuum-fusion apparatus.

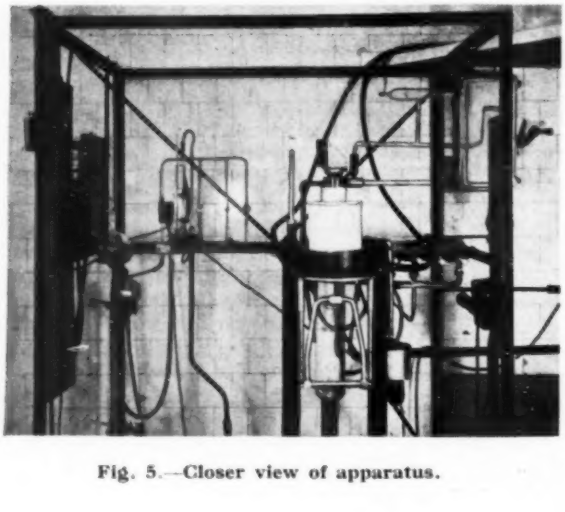


Fig. 5.—Closer view of apparatus.

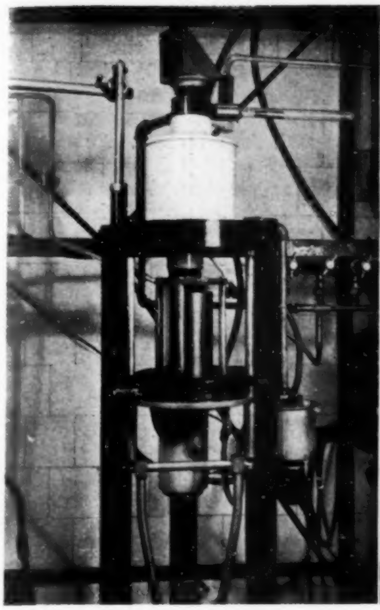


Fig. 6.—Furnace in process of assembly, 1.

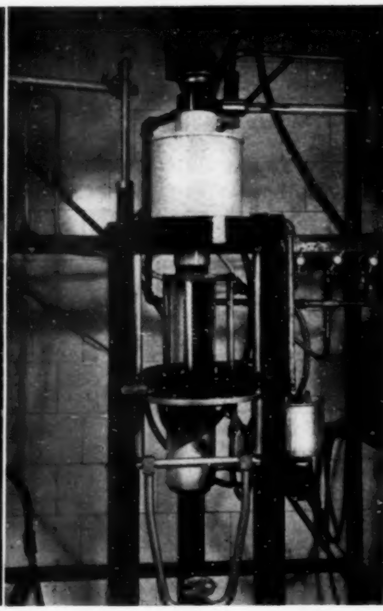


Fig. 7.—Furnace in process of assembly 2.

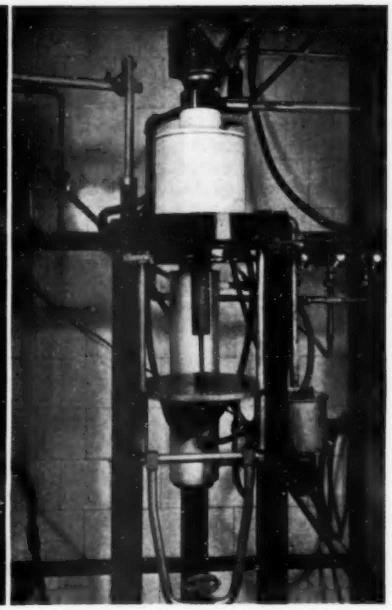


Fig. 8.—Furnace in process of assembly, 3.

The furnace is easily dismantled by unscrewing the hand-wheel underneath the furnace, after which the interior can be lowered on its base-plate, the whole assembly being guided during this movement by cylindrical sleeves fitted around the two vertical rods. Figs. 6, 7, 8, show the furnace in three successive stages of being dismantled, and a study of these photographs, together with the diagrammatic sketch (Fig. 9) will elucidate the internal construction of the furnace already described.

Composite asbestos sheet cut into the form of rings is used as an insulating material to separate the electrically connected rings from the rest of the furnace, which is itself earthed by connection with the water supply. These rings are greased on their outer edges in order that the furnace may be vacuum-tight.

The steel samples are machined to cylinders $\frac{1}{2}$ in. long and $\frac{9}{16}$ in. in dia., each weighing about 15 g., two such samples being normally used together for a determination. These samples are placed in a horizontal glass tube waxed into a " Staybrite " steel collar, which is in turn tapered and fitted into the head of the furnace with the aid of vacuum wax. The collar has an elongation at its tapered end which projects into the furnace head and enables the samples of steel to be dropped into the crucible from a position vertically above. The furnace head is in the form of a steel tube placed vertically above the crucible, and in this way spattered particles

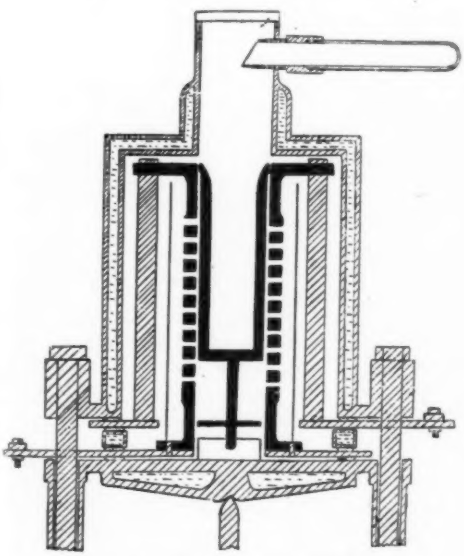


Fig. 9.—Diagram of furnace.

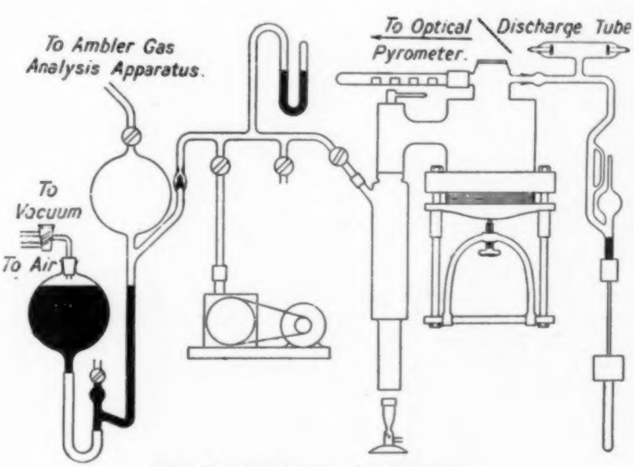


Fig. 10.—Diagram of apparatus.

are not lost or allowed to come in contact with any refractory material, but merely fall back into the crucible.

An inspection window is provided at the top of the furnace, and consists of a plane silica disc waxed in position. Temperature measurements are made through this window by reflection from a mirror placed above it, using a disappearing-filament pyrometer. Suitable correction is made for the absorptive effect of the silica window and of the mirror. It is found, however, that such temperature measurements cease to be reliable after the steel is melted in the crucible, owing to the deposition on the silica window of a small amount of metallic manganese volatilised from the molten steel. Once the correct temperature has been attained, it is therefore, maintained by control of the power input and the transfer of heat to the cooling water.

The power supply is from the A.C. mains through a multi-tapped transformer, and is passed through an over-load cut-out and a variable choke to make the finer adjustments of the current. The voltage applied to the furnace varies between 40 and 80 v. and the current between 100 and 160 amp.—the resistance of the hot carbon spiral is thus of the order of 0·5 ohm. The normal temperature of operation is 1,650° C., and the temperature at which the furnace is out-gassed is from 2,050° to 2,100° C.

A diagram of the assembly of the apparatus is shown in Fig. 10.

In the middle of the body of the furnace a 1·75 in. steel tube connects to a large steel tap fitting directly over a 4-stage Gaede mercury-vapour pump. A feature of the apparatus is the shortness of this connection, which is actually only 2·5 in. long and permits the gases to be swept from the furnace at a high rate, with the result that the pressure maintained in the furnace, even when gas is being liberated in it, is very low. In actual working, the pressure does not normally rise above 10^{-2} mm. of mercury, even when samples of steel of high "gas" content are being melted, whilst the pressure existing before the addition of a sample is of the order of 10^{-4} mm. Pressure readings are made with the aid of a McLeod gauge attached to one side of the steel framework in which the apparatus is cradled.

The backing pump is of the 2-stage oil type, and when not being used to back the mercury-vapour pump can be employed to operate the Töpler pump into which the gas liberated in the furnace passes. The capacity of the Töpler pump system is about 760 ml. so that 1·0 mm. of mercury pressure in it corresponds to 1·0 ml. of gas at atmospheric pressure. Thus, after a determination the pressure rises up to about 5·0 mm of mercury, and one sweep with the Töpler pump transfers a previously calibrated fraction of the total gas into the gas-analysis apparatus, the remainder of the gas (about one-fifth of the total) being pumped off to waste.

The gas-analysis apparatus is of the standard "Ambler" type, this being especially suitable for the manipulation of small quantities of gas. The gas samples are analysed for carbon dioxide, oxygen, carbon monoxide, hydrogen, nitrogen and methane, but never have appreciable quantities of carbon dioxide, oxygen or methane been observed.

Mode of Operation

The steel samples having been weighed and put in a definite order in the sampling tube, the silica window at the top of the furnace is removed and the crucible containing the steel of the previous determinations is withdrawn through this aperture. A fresh crucible is then put in its place, and, after the silica window and the sampling tube have been waxed in position again, the furnace is evacuated with the oil pump. As soon as the pressure is below 1 cm. of mercury the water supply to the mercury-vapour pump is turned on, and this automatically turns on the gas supply to the burner heating the pump, the mechanism for this operation consisting of a mercury cut-out for the gas, the level of the mercury being controlled by a mild-steel plunger actuated by a solenoid which is in turn controlled by the water pressure in the jacket of the mercury-vapour pump.

After about 10 min. the pressure will have fallen below 10^{-2} mm. of mercury, and the power to the furnace is then switched on so as to bring the temperature up to about 1,500° C. A brisk evolution of gas occurs, and as this subsides the temperature is gradually raised up to 2,050–2,100° C. This is usually accomplished at the end of the afternoon (the previous determinations having been made in the morning) and, although the out-gassing need only take a few hours, the furnace is generally left at temperature under vacuum all night ready for determinations to proceed on the following morning. It should be observed here that the entire apparatus has been designed to be as automatic as possible, so as to require a minimum of attention. The backing pressure is automatically maintained within prescribed limits, the cooling-water supply is automatically circulated and is independent of the main water supply, the mercury-vapour pump has the device already referred to, so that it may not be overheated, and the power to the furnace itself is automatically switched off should the pressure in the furnace rise abnormally.

During the initial period of pumping down and out-gassing, observations of pressure are made by means of a small high-frequency leak tester acting upon a discharge tube connected by glass tubing to the furnace.

When out-gassing is completed the temperature is lowered to 1,650° C., and after about 20 min. the Töpler pump is evacuated and a "blank" is determined over a period of an hour. The "blank" is usually between 0·5 and 1·0 ml. per hr., 25% of which consists of carbon monoxide, 55% of hydrogen and 20% of nitrogen. This "blank" seldom amounts to more than a few per cent. of the actual gas being determined, and since it has been found to be constant within narrow limits, it does not affect the value of the results obtained.

The system is then re-evacuated by means of the oil-pump and the Töpler pump, and a sample of steel is pushed into the crucible from the sample tube with the aid of a powerful electro-magnet. After about 10 min. the bulk of the gas from the sample has been given off (as shown by the McLeod gauge), and after a further 5–10 min. the gas collected in the Töpler pump is passed into the gas-analysis apparatus for measurement and analysis.

The Töpler pump is then re-evacuated and another sample is dropped into the crucible, so that while this sample is being de-gassed the gas from the previous sample is being measured and analysed. There is just time to complete the gas analysis during the 15–20 min. that a sample is being de-gassed, so that in this way

a series of 6–8 samples can be estimated for oxygen, as well as hydrogen and nitrogen, in 2·5–3·0 hr.

From the account given it will be seen that this apparatus is relatively simple in construction, yet its vacuum equipment is such as to maintain an enormous sweeping rate for the gas—a point which has been shown to be necessary for reliable results. In addition, its speed of production of results and the small amount of attention that it requires make it admirably suited for routine determinations of oxygen, and also of hydrogen and nitrogen, in steel.

Method 2.—Gravimetric Aluminium Reduction Method*

Based on the method of Gray and Sanders.

A 24 in. × 1 in. dia. silica tube closed at one end is heated by means of a carborundum rod furnace. By way of a ground joint, Pyrex adaptor and stopcock, the tube leads to a mechanical oil pump. The filed and degreased sample, weighing approximately 10g, consists of five discs. $\frac{1}{12}$ in. thick, cut from $\frac{1}{2}$ in. bar; these are sandwiched in a $4\frac{1}{2}$ in. × $\frac{3}{4}$ in. × $\frac{5}{8}$in. graphite boat between overlapping strips of freshly-filed aluminium; the strips are $2\frac{3}{4}$ in. long × $\frac{9}{16}$ in. wide × $\frac{1}{8}$ in. thick, and weigh approximately 14 g. The graphite boat is shaped by means of steel tools, to the exclusion of abrasives. Evacuation is carried out for 20–30 min. at room temperature, and then the tube is introduced into the furnace at 1,150° C. When the temperature of the tube has attained 1,000° C.—i.e., after about 4 min.—the tap is closed, and the non-oxidising gases evolved from the graphite are allowed to accumulate in the tube. The tube attains the furnace temperature of 1,150° C. after 10–15 min. and this is maintained for one hour.

When cold, the iron-aluminium melt is detached from the boat, and placed in 350 ml. of cold 1 : 1 hydrochloric acid. No external heating is applied. Where the steel contains titanium, a pre-addition of tartaric acid is made to the hydrochloric acid. The solution is oxidised with 40 ml. of nitric acid (S.G. 1·42), a small quantity of ashless pulp is added, and the mixture is allowed to settle at about 70° C. The insoluble alumina is collected on a paper pulp filter; any persisting carbides from high-carbon steels are previously removed by treatment with ammonium persulphate.

The filter is washed with water and warm 1 : 1 hydrochloric acid, then with hot water and a hot 3% solution of sodium carbonate, and finally with water. The residue is ignited in platinum at 1,000° C., treated with a few drops of sulphuric and hydrofluoric acids, reignited and weighed. After deduction of the blank obtained from 14g. of aluminium and 0·20 g. of a steel of very low oxygen-content, treated throughout in the same way, this weight of alumina is calculated back to percentage oxygen in the steel.

Under these conditions, the method gives a blank of reasonably low proportions, viz., about 0·0004 g. Al_2O_3 or 0·002% of oxygen.

Method 3.—The Alcoholic Iodine (Stirring Method)†

The reaction vessel (Fig. 11) consists of a tap funnel A fitted with a head carrying a stirring gear and with a re-entrant tube to accommodate a thermometer. The apparatus is mounted on a stand so designed as to permit tilting during filtration. The sample, in the form of a thin-sectioned disc weighing 8–12 g., is placed in the funnel A, the head is placed in position, and the joint is sealed with vacuum wax. The air is driven out by passing dry nitrogen for about 3 hrs. With tap D closed, the nitrogen is passed in through tap B and escapes through tap C, the apparatus being tilted on its side during the operation, following which taps B and C are closed and the ground joint above tap D is fitted to the filtration apparatus.

The iodine solution is then filtered through tap D, air being excluded by maintaining some liquid above the tap. Tap B is connected to the evacuating system to assist in the filtration. Taps D and B are closed just before all the solution enters, and the apparatus is disconnected. The funnel A, fitted with the stirring gear is normally maintained at a temperature of 60–65° C. by a special oven, consisting of a box of insulating material inside which, on three sides, are resistance mats; the fourth side slides out in order that the vessel can be inserted. Slots are provided in the top and bottom of the box, so that the head and tap of the vessel can project, and heating of these parts is thus avoided.

The stirrer is connected by means of a piece of rubber pressure tubing to the spindle of a small motor. Tap B is connected to the nitrogen supply and opened. The liquid is stirred, at a speed of 1,500–2,000 r.p.m., until solution of the steel is complete. During the stirring, a slight positive pressure of nitrogen is maintained through the tap B. Solution of the sample, using a weight of about 12 g. should reach completion within 50–90 mins. When solution is complete, the stirrer is disconnected from the motor and the apparatus is placed in position in the filtration apparatus.

The bottom end of the stirrer is then moved close to tap C in order to collect any small undissolved pieces of steel. It is then drawn up clear of the surface of the liquid. While the liquid is being filtered nitrogen is admitted through tap B. The apparatus is tilted on its stand so that the bulk of the residue remains in the reaction vessel and does not reach the filter until most of the liquid has passed through, when the apparatus is turned to a vertical position and the filtration completed.

The filter arrangement consists of two ground-glass flanges, the lower one of which is fitted with a sintered glass disc. The flanges are smeared with vaseline and a No. 50 Whatman filter is fitted in place. To ensure a tight joint, the flanges are held together by means of spring clips. After fitting together, the filter is washed two or three times with dry methyl alcohol with slight suction, the washings being received in vessel P. The whole apparatus is then assembled as shown in Fig. 12.

The Nitrogen Apparatus.—The nitrogen passes through a soda-lime tube to remove traces of carbon dioxide, then through concentrated sulphuric acid for drying purposes, and into a tube heated to 600° C. The tube contains spirals of copper and nickel gauze. Next follows another sulphuric acid drying bottle and a tube, heated to 800° C. containing pure iron turnings. Finally, the gas passes over a mercury safety trap through a tower containing silica-gel to the tap which controls the entrance to the filtration apparatus.

* Stevenson and Speight, *J. Iron Steel Inst.*, 1941, No. 1, 326 p.; 1943, No. 2, 242 p.).

† Rooney et al. *J. Iron Steel Inst.*, 1935, No. 1 249; First, Second, Third and Fourth Reports of the Oxygen Sub-Committee, Iron and Steel Inst., 1937, 1939, 1941 and 1943.

Note on Filtration.—The Whatman filter paper is dried in a steam oven for about half-an-hour and then immersed in alcohol. Evacuation of the apparatus can be avoided so long as no air is allowed to enter the reaction vessel during the filtration. For the final filtration of the residue, evacuation can be avoided if the space above the filter is filled with dry alcohol before fitting the reaction vessel in the ground joint.

Iodine Solution.—Seventy grammes of Analar standard iodine, previously dried by storing over silica-gel, are placed in the tap funnel K and dissolved in 600 ml. of pure dry methyl alcohol by shaking or stirring.

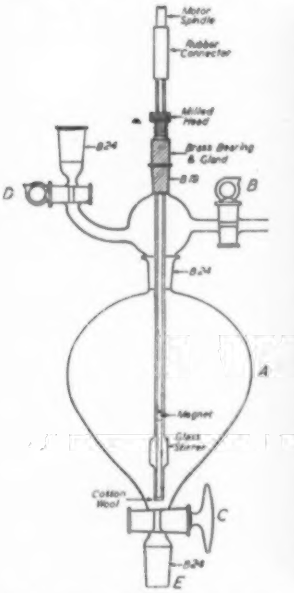


Fig. 11.—Reaction vessel used in alcoholic iodine methods.

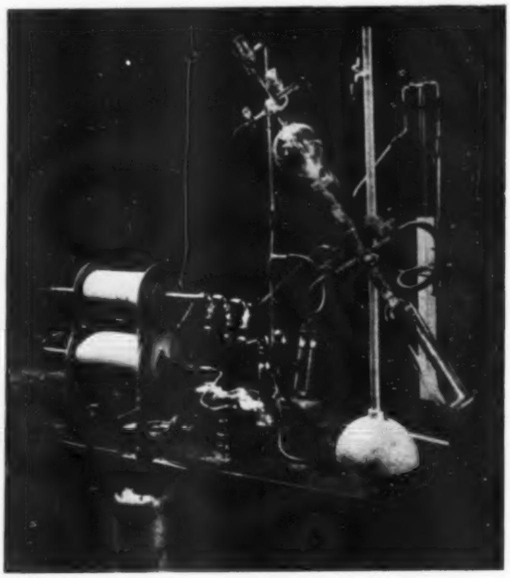


Fig. 12.—Assembled apparatus for alcoholic iodine method.

Methyl-Alcohol.—By means of sensitive hydrometers, the water content of the methyl alcohol may be accurately evacuated. The following table shows the relationship between specific gravity at 20° C. and the water-content.

Sp. Gr. (20° C.)	% Water
0·7912	0·01
0·7913	0·05
0·7915	0·12
0·7916	0·15
0·7918	0·22
0·7920	0·29
0·7922	0·36
0·7924	0·42
0·7926	0·49

Should the specific gravity exceed 0·7918 it is necessary to distil over calcium.

After-treatment for alcoholic iodine residues from steels other than those low in carbon and phosphorus*

Transfer the residue, without drying, to a reflux condenser and boil with 10% solution of ammonium tartrate for 3 hours, and allow to stand overnight. Collect the residue so treated on a filter and wash with 10% ammonium tartrate solution.

This will remove any retained iron carbide, any additional (excessive) iron oxide and silica, as well as carbon-absorbed aluminium, and will reduce substantially the phosphorus contamination.

*Speight. Fourth Report of Oxygen Sub-Committee. *Iron and Steel Inst.*, 1943.

After-treatment for alcoholic iodine residues from aluminium—alloyed or aluminium—killed steels and steels containing large amounts of chromium.

Wash the unignited residue free from iron iodide with alcohol and with hot water. Twice wash alternately with hot 3% sodium carbonate solution and cold 1 : 20 hydrochloric acid. Finally, wash with hot water. Ignite at a moderate temperature in order to remove free carbon and then digest on a hot plate with 1 : 1 sulphuric acid until the insoluble residue is white in colour. Evaporate to fumes, cool, dilute, heat to boiling, and filter. By means of hydrofluoric acid, determine silica in the residue, which consists mainly of alumina, and also examine for any traces of iron and manganese. The other constituents are determined in the filtrate, which also contains the soluble aluminium compounds.

This treatment serves to remove alumina derived from other aluminium compounds and carbon-absorbed aluminium.

Method 4.—The Chlorine Method*

Description of the Apparatus

A sketch of the apparatus is given in Fig. 13. The chlorine, contained in a 70-lb. gas cylinder, is prepared electrolytically and purified by a liquefaction process. The first 50 litres of gas from each new cylinder are passed to the atmosphere, since the bulk of any gaseous impurities in the chlorine is contained in this fraction. The gas is led from the cylinder through concentrated sulphuric acid in the wash-bottle A and calcium chloride and phosphorus pentoxide in the drying towers B and C, respectively. The rate of flow of chlorine is approximately 15 litres per hr.

The steel sample, contained in a fused-silica boat G, is chlorinated in the Pyrex glass reaction tube E. This tube has a ground-glass stopper F, fitted with an inlet for gas and a thin Pyrex tube H carrying a chromel-alumel thermocouple T. In order to make the temperature measurement as accurate as possible the tube H is arranged so that its end is right in the boat and in immediate contact with the steel. The length of the tube is such that the end of the thermocouple can be placed at any point along the boat G when in position.

The wiring of the electrically-heated furnace D is arranged so that it is evenly heated throughout its whole length. This ensures that all the volatile chlorides are carried away to sublime in the collecting bottle L, which is connected to the reaction tube E by means of the ground-glass joint K. The bottle L is fitted with an exit tube for excess chlorine gas.

* Colbeck et al. *J. Iron and Steel Inst.*, 1936, No. 2, 251 p. : First, Second, Third and Fourth Reports of the Oxygen Sub-Committee, Iron and Steel Inst., 1937, 1939, 1941, 1943.

The bend J in the reaction tube fits as closely to the furnace D as is practicable, so that the chlorides fall into the bottle L and do not block the reaction tube itself.

Two methods of obtaining a sample for chlorination are employed. In the first, the bar is skimmed up in a lathe until all surface marks are removed, and thin cross-sectional slips are then cut from it, each approximately 0·2 in. long. Sufficient of these slips to make 10–15 g. weight of sample are taken for each determination. With bars of $\frac{3}{8}$ in. dia. or less the slips fit into the

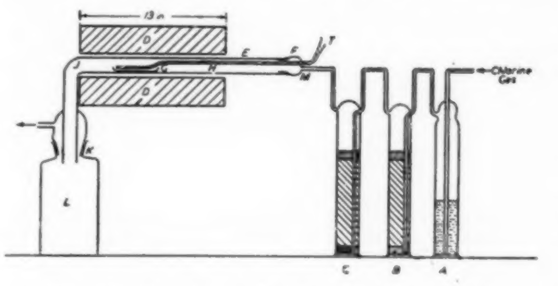


Fig. 13.—Apparatus for the chlorine method.

boat in such a way that it is possible to bring the tip of the sheathed thermocouple close to them by making the couple dip down at the front of the boat and then run parallel just above the specimens to the other end of the boat. If the bars are from $\frac{3}{8}$–$\frac{3}{4}$ in. in dia. each slip is carefully folded over in a vice. The samples are dried in alcohol before weighing and chlorinated immediately.

In the second method, one solid test-piece cut from the skimmed bar may be used, provided that it will fit well down into the boat. It has been found possible, for example, to use one test-piece cut from a bar of $\frac{3}{8}$ in. dia.

Procedure

The reaction tube E, the collecting bottle L and the ground-glass stopper F carrying the thermocouple sheath are rinsed with methylated spirits and dried in an air oven at 110° C. overnight. The apparatus is then assembled as shown in Fig. 13, but the drying train is not connected to the reaction tube. The furnace D is switched on and the temperature raised to 300° C. This temperature is maintained for about 10 min., the furnace is switched off and the reaction tube is brought rapidly to room temperature by means of a stream of dry compressed air introduced at M.

The boat G is dried by heating it in a Bunsen flame to a dull red heat; it is allowed to cool in a desiccator. The weighed sample is then placed in the boat and introduced into the reaction tube E. The drying train is connected up at M and the flow of chlorine started. The boat G is not placed in the centre of the furnace D, but nearer to the bend J, so that the volatile chlorides have a shorter distance to travel.

When chlorine has been passing through the apparatus for $\frac{1}{2}$ hr., the furnace D is switched on and the temperature is raised slowly to between 150° and 160° C. The furnace is then switched off, as the residual heat is sufficient to start the reaction between the chlorine and the sample. The exothermic reaction raises the temperature of the steel, but by switching off the furnace at 150–160° C., the temperature should never exceed 300° C. As soon as the temperature begins to fall the furnace is switched on and maintained at 350° C. throughout the test. When no trace of volatile chlorides can be seen entering the receiving bottle, chlorination is complete, but the stream of chlorine is continued for a further 15 min.

The furnace is then switched off and the reaction tube cooled to room temperature, the passage of chlorine being continued. The chlorine is shut off, the drying train A, B and C is stoppered to prevent the inlet of air, and the boat and its contents are removed from the reaction tube immediately.

The contents of the boat are washed out with water at once, and the residue is filtered through a 5·5 cm. No. 42 Whatman filter paper.

Test Run, using a Standard Steel

Experience over the past three years has indicated that before commencing work on a fresh series of steels it is necessary to carry out a preliminary test, using a steel the oxygen content of which is known. Also, this test run is always carried out when alterations have to be made to any part of the apparatus or when a fresh cylinder of chlorine is brought into operation.

THEORY OF THE METHODS*

Method 1

Apart from such compounds as sulphides, carbides etc., it is generally conceded that non-metallic inclusions of a normal killed steel have two or three possible origins, viz.:—

(1) Reaction products of the deoxidation with silicon, manganese, and aluminium coalescing with ferrous oxide to yield silicates, spinels, etc.
(2) Reaction between ferrous oxide, manganous oxide, and the refractories of the ladle and casting pit, yielding products similar to those in (1).
(3) In addition to the above, there may be present, on occasion, entrapped slag particles, which may be acid or basic, depending on the method of manufacture.

With the exception of the infrequently occurring basic oxides (CaO, MgO) in group 3, reduction of all the oxides is complete. The combined oxygen has a preferential affinity for carbon, with formation of carbon monoxide. In the fractional vacuum-fusion method, use is made of the varying degrees of readiness with which the oxides respond to reduction. Sulphides do not suffer decomposition under the conditions of the vacuum-fusion method.

Method 2

The method is based on the production, under controlled conditions, of an iron-aluminium-alloy the composition of which approximates to that of the compound $FeAl_3$. The total oxygen is present in steel as FeO, Fe_2O_3, MnO, Al_2O_3, SiO_2, etc., and in complex combinations of these oxides, which are dissociated by the large excess of aluminium, with the quantitative production of alumina. Any entrapped oxygen-bearing gases are also dissociated to form alumina.

The sodium carbonate wash is designed as a safeguard against any slight precipitation of silicic acid.

In determining the blank, the 0·2 g. of very low oxygen steel prevents the adherence of the aluminium to the boat, promotes rapid solution in the acid solvent, and prevents the formation of a white furry covering

* See also Consideration of Methods.

of aluminium carbide. The yield from the 0·2 g. of steel is negligible.

The addition of tartaric acid to the hydrochloric acid, before immersion of the alloy for its solution, prevents the precipitation of titanium compounds of an insoluble character.

Method 3

Methyl alcohol appears to be unique in its suitability as the solvent. It is commercially consistent in quality, and is a good solvent not only for iodine, but what is equally important, for the metallic iodides formed. The presence of water does not affect the yields of silica, oxide of manganese, alumina or phosphorus pentoxide, but it causes a serious increase in the percentage of iron oxide in the residue. The retention in the residue of soluble constituents of the alcoholic iodine is a true absorptive effect, and therefore their elimination by means of washing is not possible. Many examples occur in analytical chemistry in which absorptive contamination is largely overcome by the use of a solution of remotely different characteristics. In this case, the solute used must be such as not to survive the ignition in any way.

Method 4

In the chlorine method, in which we have a "dry" reaction, the adsorptive effect of the separated carbon is considerably less evident than in the alcoholic iodine method, and subsequent contamination is on a very much lower scale. The interference of most constituents is so very slight as to be without significance, and even the retained amount of phosphorus is small.

High Manganese Steel and Its Deposition by Arc Welding

By R. W. Edwards

The characteristics of high manganese steel and its deposition by arc welding are discussed and some of the problems considered in perfecting a suitable electrode and technique for building up work-hardening surfaces. It is suggested that developments may lead to a highly refined technique for the production of a work-hardening weld deposit capable of resisting many diverse variations of treatment, heating, and abrasion applied by industrial usage.

THE necessary reinforcing of wrought iron, mild steel, cast steel, etc., by hard-wearing metals has been greatly emphasised by current austerity conditions, more particularly so where conditions of abrasion exist. In pre-austerity days low abrasion resistant steels could be replaced in many cases by parts fabricated of Hadfield 14% Mn steel or by steels of the Cr/Ni, or tungsten type; but, for economy purposes, this reinforcement is now carried out by deposition by arc welding of a high manganese steel giving a work-hardening deposit of ca. 500 Brinell hardness.

Characteristics of High-Manganese Steels

The principles of work-hardening manganese steels are such that the steel shall be austenitic; this structure, when subjected to abrasion, and, or, impact has the property of elongation of the surface crystals giving a martensitic layer of glassy appearance, and of ca. 500 Brinell hardness, surmounting a tough resilient bed of austenite. This work-hardened layer has been shown to attain a thickness of 0·8 in. in a steel railroad frog approximately 6 in. thick.[1]

Guillet[2] has constructed a graph (Fig. 1) showing the constitution of slow cooled manganese steels whereby it is possible to ascertain whether a selected steel will be of austenitic structure or not by observation only of the carbon and manganese contents.

Hall[3] also records figures on a chart modified from Guillet (Fig. 2) showing the valuable austenitic manganese steels, i.e., those which are truly austenitic after

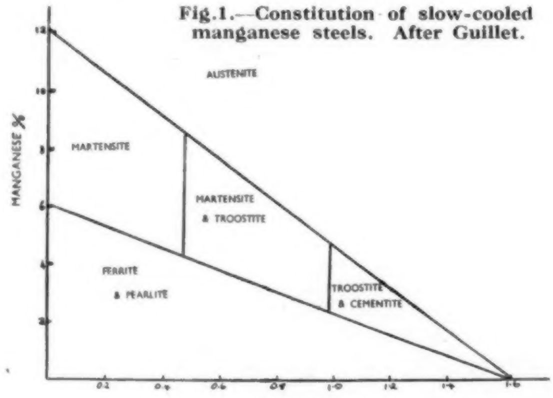


Fig. 1.—Constitution of slow-cooled manganese steels. After Guillet.

quenching in water from ca. 1,000° C, such as Hadfield steel[4] (12–14% Mn, 1·0–1·25% C and 0·25–0·4% Si), the iron being then in the γ condition. The equations of the lines given by Hall are :—

$$C = 1{\cdot}075 + \frac{0{\cdot}1 \text{ Mn}}{3} \quad \text{and}$$

$$C = 1{\cdot}075 - 0{\cdot}04 \text{ Mn}$$

Not all of the steels lying within the boundary lines XY and WZ are of sufficient strength and toughness for the service required, however, and the optimum composition generally required is :—

Mn 11·0% min., C 1·0–1·4%, Si 0·3–1·0%
S 0·05% max., P 0·1% max.,

1 Rice, *Iron Age*, September 11th, 1941.
2 Guillet, *Comptes rendues*, 1905, Vol. CXL.
3 J. Howe Hall, *Metals Handbook*, 1939, pp. 567 *et seq.*
4 Hadfield, *J. Iron and Steel Inst.*, 1888, ii, 41; *Proc. Inst. Civ. Eng.*, 1888, 93, iii.

although more recent steels have a tendency to a lower manganese content than was originally considered necessary. Carbon over 1·4% is undesirable as it increases the tendency of the steel to crack in heat treatment, but no appreciable effect upon the physical properties can be found on variation of the silicon content from 0·3% to 1·0% Austenitic steels are characterised by great toughness, and show greater elongation and less necking down in tensile tests than do the ferritic steels, but their peculiar merit lies in their resistance to abrasion rather than to any particular static or fatigue strength. This work-hardening effect is obtained as indicated above by stretching of the austenitic surface crystals to form a glassy layer of martensite, although it has been considered[5] that this film may perhaps be chiefly cold-worked austenite which is responsible for the wear resistance, as light abrasive

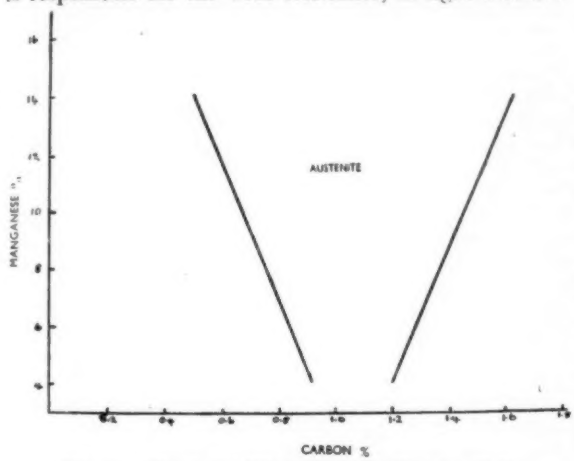


Fig. 2.—Chart modified from Guillet by Hall.

pressure is insufficient for the formation of this film and merely results in the rapid wearing away of the steel.[3]

As cast, manganese steel is quite brittle, considerable free carbide occurring in patches and in a network between the austenite crystals (Fig. 3). The heat treatment usually applied is that of quenching in water from 1,000°–1,075° C., but when the carbon content is in excess of 1·5%, free cementite is found in amounts which increase in proportion to the carbon content of the metal and after such treatment the metal is mainly martensitic with free cementite and of decreased ductility[6]. With steel of the correct composition a similar effect is caused by too low a temperature before quenching, or by a time lag between heating and quenching.

Reheating at ca. 370° C. causes partial transformation of the austenite, and liberation of the carbide, causing the metal to become brittle. The hardness of the cast and heat treated steels is in the region of 180–200 Brinell : a cold-worked surface shows, however, 450–500 Brinell. The selection of a manganese steel for any particular purpose depends upon the correlation of varying qualities and static properties. Generally, for maximum wearing characteristics, the most ductile steel which will give a yield strength sufficiently high to avoid distortion in service will be best. Thus a steel of

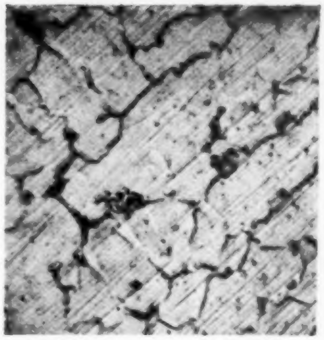


Fig. 3.—Austenitic manganese steel showing free carbide patches and network.

9–11% Mn with the correct amount of carbon will have a higher yield stress than a steel with more than 11% Mn.

For deposition on to rails of the Hadfield steel type, and for general reinforcement, Deglon[7] has recommended that the hardness of the freshly deposited metal should equal that of the rail but that after work-hardening should show an increase of 100 points (it is not stated to which scale the figures refer to).

In the welding of carbon bearing, austenitic manganese steels, as usually performed with an electrode of composition equal to that of the parent metal, the edges of the weld are weak, as the metal adjacent to the weld is likely to cool slowly enough to permit segregation in the one that has a sufficient sojourn in the dangerous range of temperature with consequent embrittlement (Fig. 4). This carbide precipitation impoverishing the matrix of this one is thought to favour also intergranular corrosion near the work.

Within recent years several improvements have been made regarding the actual structure of the deposited metal, mainly concerning the effects of small percentages of added elements. The most important addition has been that of nickel to the extent of 3–5%. It has been shown[8] that this addition improves the general qualities of the weld metal under air cooling, and eliminates the necessity for quenching. These nickel-bearing electrodes (preferably also of lower carbon content than the base metal) blend sufficiently well with the parent metal so that the weld does not materially injure the

Fig. 4.—Segregation after welding with 14% Mn electrode (etched).

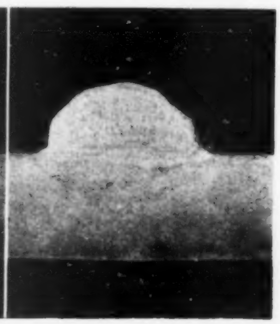


Fig. 5.—Weld deposit from 14% Mn, 3/8% Ni electrode.

adjacent steel (Fig. 5) although it has been claimed that nickel-bearing deposits are rather brittle.[9] The addition of small amounts of chromium appear to improve the performance of the manganese steels by increasing the initial hardness of the deposit, thus

5 Howe and Levy, *Tr. A.I.M.E.*, 1915, Vol. 51, p. 881.
6 Rollason, "Metallurgy for Engineers," London, 1940, p. 141.; Hall, *loc. supra cit.*

7 Deglon, "Symp. Welding," Iron and Steel Inst., 1935, Vol. 2.
8 Hall, A.S.T.M., "Symposium on Steel Castings, 1932, pp. 200–214.
9 U.S. patent 2,038,178.

essening the amount of cold work or deformation necessary to develop the required skin hardness, and by increasing the yield strength, but the addition must be made with care. Up to 1·0% Cr may be added without reducing the shock resistance although over 0·5%, elongation figures rapidly decrease. If the carbon content is greater than 1·3%, the steel will be brittle and 1·5% is about the maximum it is desirable to include.

An alloy of 13–15% Mn, 3–5% Ni with 4% Cr is finding application in resisting wear combined with temperatures approaching red heat.[13] The addition of 1% Cu to a 14% Mn. steel with 5% Cr is helpful in increasing the ductility, but the steels of 5% Cr are generally inferior to those of 3% Cr, hence the addition of 3% Cr and 1·5% Cu is desirable in Hadfield steels to be used under conditions causing flow in the standard applications, i.e., rails, frogs, etc.

Carbon should normally be kept between 0·8% and 1·1% except when ductility is not of prime importance when it may be increased to 1·3–1·4%.

The tendency of the metal to stretch under heavy pressures has to a certain extent been counteracted by the addition of molybdenum up to 1% although when this element is added in quantity to prevent stretching there is a tendency to decrease the toughness of the steel to a certain extent; the presence of up to 2% Cu or Ni overcomes this loss, however.

High Manganese Steel Welding Electrodes

From correlation of the above facts and apart from considerations of miscibility, it would appear that the optimum composition of an electrode for welding high manganese steel should be such as would deposit metal of the composition :—

C 0·5–1·0%	Cr. ca. 3·0%	Si ca. 0·5%
Mn 11–14%	Mo ca. 1·0%	P 0·1%
Ni 4–6%	Cu ca. 1·5%	S 0·1%

The deposition of metal by arc welding, of any composition required may be obtained in two main ways :—

(*a*) deposition dependent upon the coating composition.

(*b*) deposition dependent upon the core wire.

In the former case, the core wire is usually of mild steel and the alloying elements are contained in the coating, usually as ferro alloys. This method is, however, far from efficient as the composition, and hence the quality, of the weld metal is dependent upon characteristics of the welder, current, humidity of the coating, etc., some manufacturers do, however, rely upon this method.

In the second method, the core wire approximates fairly closely to the composition desired in the weld metal, and the coating is of a non-reactive type merely acting in the nature of a non-alloying flux and protective. This method is far less dependent upon welding characteristics and is employed by the majority of electrode manufacturers.

There is, of course, a third method which incorporates both of the above, utilising a core wire of composition approximating that required in the deposited metal, and coated with a mineral agglomeration containing alloying elements in sufficient amount to ensure that the figures required of the weld deposit do not fall below the minimum allowable.

Some American firms also manufacture an electrode in which the alloying elements and fluxes constitute the core of a tube of mild steel; this, however, is as unsatisfactory as method (*a*) above for practically the same reasons. Some manufacturers issue several surface hardening electrodes which are not of the austenitic manganese type, being of the Cr/Ni series, Tungsten type, or merely heat treated carbon steels, etc. These are not considered in this report.

Patent Position

Attempts to collate data from published patents yield meagre results as, unfortunately, there is a lack of essential information. The details given of any particular electrodes have usually very wide limits. The German patent position, apart from the lack of information generally, is very obscure, as the only austenitic steels quoted are those of the Cr/Ni series.

In the U.S.A. several patents have been taken out[10] for fluxes for manganese steels, and also for the production of wires for electrodes of composition varying from 11–15% Mn, 3–5% Ni, and 0·8–1·4% C with small additions of molybdenum. The Lincoln Electric Co., Ltd., have claimed a rather comprehensive patent[9] embracing in the weld deposit inclusion of Ni or Co and Mo, Ti, and/or W in the proportions of 0·1–10% and 0·1–2·0% respectively with Mn varying from 7–15% and carbon from 0·5–1·2%.

Patents have also been claimed[11] for austenitic steels to be used as welding electrode wires having the composition C 0·8%, Mn 13·5% and Si 0·95% in which it is stated that an increased hardness of the steel is obtained by increasing the carbon content, thus 0·8% C builds up to 450 Brinell whilst 1·2% C gives a final hardness of 520 Brinell. Also affirmed is the fact that the carbon content controls the amount of manganese and nickel required for the production of austenitic deposits, and that 11–14% Mn steels are controlled largely by the carbon-nickel relationship. The carbon content of Manganese steels is approximately 10% that of the Mn content, but the quantity of nickel necessary with 15% Mn and 1·5% C is 8–10% for the full use of the nickel to be manifested. The high nickel content is, however, obviated by the use of silicon. A further point of interest is the use of cobalt to replace the nickel in the same percentages.

Another claim is that appertaining to the use of a manganese content in excess of 11% in which the Mn/C ratio is 12 : 1 and the Mn/Ni ratio 4·04 : 1 with Si from 0·6–0·9%.

Welding Characteristics

For welding with high manganese electrodes, most manufacturers indicate the use of D.C. power with reversed polarity, although A.C. power may be used. The current employed depends upon the gauge of the electrode as follows :—

10 S.W.G.	90–130 amps.
8 S.W.G.	120–140 amps.
6 S.W.G.	140–175 amps.
4 S.W.G.	160–180 amps.

A normal arc length is maintained with the electrode held at an angle of approximately 70° to the work. It has been found when welding with a high manganese electrode, that, owing to the increased electrical resistance of the core wire, it is necessary, in order to obtain the correct amperage, to adjust the generator to a

10 U.S. patents 1,876,738, 1,947,167, 2,038,178, 2,060,948.

11 U.S. patents 1,876,738, 1,947,167.

12 Gregory, *Metallurgy*, London, 1942, pp. 141–5.

13 Hall, *Metal Progress*, 1931, November, Vol. 20, p. 69.

Continued on page 57

The British Industries Fair

Planned to Develop World Trade

Every sign points to the 1948 British Industries Fair at Earl's Court and at Olympia, in London, and at Castle Bromwich, from May 3rd to 14th inclusive, being as comprehensive as its predecessors. Indeed, in number of exhibitors and floor space occupied by exhibition stands, a record has been achieved. This Fair, now established as the world's greatest national trade display, is the twenty-seventh since 1915; it provides buyers with the greatest opportunity of the year to examine the latest United Kingdom products. In this review particular attention is directed to the Castle Bromwich section.

THE British Industrial Fair held simultaneously at Earl's Court and Olympia, in London, and at Castle Bromwich, near Birmingham, on May 3rd and remaining open until May 14th, is rapidly becoming recognised as the most important trade event of the year. It is undoubtedly the world's greatest national display of a country's products, and buyers everywhere are given the opportunity of seeing the progress achieved in many fields of activity in which United Kingdom manufacturers have set a very high level for quality. In addition, however, it provides an opportunity for overseas buyers to meet the principals of manufacturing firms and to discuss industrial and trade matters. The Fair is a concentrated effort to bring buyers and manufacturers together and, in many cases, new friendships will be formed, but old friends will be sought, and undoubtedly many pre-war contacts will be renewed.

The 1947 Fair, in many ways, was a record one. It was the first post-war Exhibition after a lapse of eight years, and overseas buyers had the opportunity to consider Britain's progress in relation to parallel difficulties throughout the world. Nearly 17,000 overseas visitors attended that Fair, some being from such distant parts as China, Peru, Siam, Ethiopia, Fiji Islands and Mauritius. There were 3,363 exhibitors and a total attendance of over 500,000. It is confidently expected that these figures will be exceeded at the present Fair, and every sign indicates that another record will be achieved.

Of outstanding interest at this Fair are two models of gas turbines by POWER JETS (RESEARCH & DEVELOPMENT), LTD., which demonstrate the application of a gas turbine to the highly important manufacture of nitric acid with its consequent potential cheapening of fertilisers. This can be regarded as an out of the way application for the gas turbine, but it indicates the enormous and revolutionary possibilities of this new form of power which should successfully bridge the gap between the internal combustion engine and the application of atomic energy.

The gas turbine is a British invention and the application demonstrated is only one example of applying this type of engine to a process. It is not too visionary to predict its successful application for many other chemical processes, for instance, the production of cheap oxygen, from which a whole revolution of industry may spring. Cheaper steel, cheaper coke, cheaper and more available fertiliser, cleaner industry, better transport, are all targets within the range of this power unit.

In reviewing such a comprehensive Exhibition, planned to enable overseas buyers to view a representative cross section of Britain's productive effort, so many technical advances are displayed that much more space would be needed than can be given here. As we are more concerned with the heavy industries, attention is especially directed to the Castle Bromwich section of the Fair where the engineering and hardware exhibits are housed, and an effort will be made to describe briefly some of the more interesting features. Since the heavy industries are dependent on metals and alloys, brief preliminary information will be given concerning developments in the production of these materials.

Iron and Steel

Much of the pioneer work in the production of iron and steel emanated in Britain. British discoveries and developments provided the basic knowledge on which the steel industries throughout the world have been built. Progress has continued through the years in order to meet the ever-increasing service needs of engineers and although here production has been greatly exceeded by that in the United States and in Soviet Union, in regard to quality and reliability British steel is increased, the March figures, for instance, at an annual rate of 15,117,000 tons, established an all-time record for this country. Production for the first quarter of this year was at the record level of 14,933,000 tons annual rate, 824,000 tons better than the best previous quarter of 14,109,000 tons annual rate of April/June, 1940 (Dunkirk quarter). A substantial improvement in pig iron production is also announced, but although steadily increasing it is not yet sufficient to check the continued drain on stocks.

Iron and steel are, of course, vital materials in Britain's national economy; almost all her industries are dependent upon ample supplies. On the one hand this industry draws upon the great raw material sources—coal mining, iron ore mining, collection of scrap, and makes heavy demands on the transport system for assembling these raw materials as well as limestone, refractories, etc. The iron and steel produced becomes the principal raw materials of a great many of the major industries—shipbuilding, rail and road transport vehicles, and engineering. They play a big part in agriculture, in the textile industry on which much now depends, and in mining and other major activities.

Despite the outstanding efforts of the industry the production of iron and steel does not meet the needs of the consuming industries and this has necessitated some modification in Britain's planned economy. Plant to further increase production is in course of construction, but new blast furnaces and new open-hearth furnaces, as well as supplementary equipment to work in conjunction with the furnaces, whether to displace or additional to existing plant, involves much labour, time and materials. It can be expected that as new plant is put into service

production will tend to rise, but it must be remembered that many of the furnaces are replacements, and while they incorporate the latest developments to facilitate operation and to improve the quality of the products, the actual increase in production from such furnaces may be relatively small unless their capacities are larger.

The British Iron and Steel Federation exhibit is designed primarily as an information centre on iron and steel products. Individual features indicate the extent, the location, the production achievements and development schemes of the industry. The development schemes of the industry are outlined in the plan for expansion contemplated throughout the years 1949-1952. This plan provides for an additional 1,780,000 tons of blast-furnace capacity, 1,850,000 tons of steel furnace capacity, 1,475,000 tons of cogging and finishing mill capacity, together with all the essential ancillary plant.

The research activities of the industry are too widespread to be shown in comprehensive detail; the display is simply intended to emphasise the fact that the scientific side of the industry is active and important, and demonstrations are given on the use of spectroscopy in control of converters, the use of gamma rays for non-destructive testing, the development of the heat-resisting steels for gas turbine engines, and stages in the lost wax process of gas turbine blades. It is noteworthy that the amount spent annually by the industry on research is of the order of £1,500,000.

As will be appreciated the range of products of the iron and steel industry is very comprehensive, the exhibits of Exors. of James Mills, Ltd., on their Stand D.400, include bright drawn, turned and ground round steel bars, in all qualities; bright drawn hexagon, square and flat steel bars; bright drawn special shapes; "Ledloy" steels; engineers' headed, plain and Woodruff keys; solid and split taper pins; patent grooved pins and studs; black, bright, headed and plain steel cotters; and railway permanent way fastenings.

The central feature of the James Mills' stand is a full-scale model of an express locomotive emerging from a tunnel, running on track fitted with Macbeth anchor spikes. These are a recent development for use with flat bottomed rails, which are extensively used abroad and are now being adopted on all main lines in this country also. These anchor spikes are claimed to combine economy with an exceptionally high degree of efficiency, and are considerably in advance of other types of rail fastening. This firm is again demonstrating the machinability of "Ledloy" bright steel bars on an automatic lathe at high speed.

The Guest, Keen & Nettlefolds Group are exhibiting on Stands B.627 and 526, screws of all descriptions; bright and black bolts and nuts; rivets, self-tapping screws, "Aerotight" nuts, socket screws; foundation bolts; railway fastenings of all kinds; round, square and flat steel bars; angles and channels; hot and cold-rolled strip; wire nails; grey iron castings; steel fabric reinforcement and high tensile steel reinforcing bars for roads and buildings. Telegraph ironwork; wrought iron gates and fencing; upset, drop and press forgings of all kinds; small hand tools such as spanners, wrenches, etc.; steel furniture and office equipment. They are showing several films of interest in a theatre built into the stand and capable of accommodating 48 people.

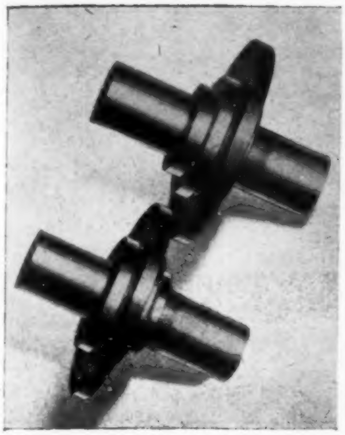
The range of drop forgings exhibited by English Steel Corporation, on Stand D.623, include finished machined aero crankshafts as supplied to Rolls-Royce, Bristol, Napier, etc., and commercial crankshafts and a special display of drop-forged discs made recently for the De Havilland "Ghost" Jet engine which powered the "Vampire" height-record aircraft. It is, of course, impracticable to show large forgings up to 160 tons in weight, and these are dealt with pictorially. The range of alloy steels for which the firm is famous, is represented by two 7 ft. 6 in. columns of precision-ground bars, one of round bars and one of hexagon bars.

In addition to the more conventional types of car suspension, such as coil and laminated springs, English Steel Corporation are now making, on a large scale, torsion bars from their own special alloy steels. Several types of bars are shown and there is an interesting exhibit in the form of a torsion bar which underwent a test in which it was twisted to simulate 5,558,640 bumps of maximum range, and during this test, showed no signs of fatigue. Various types of railway buffer and suspension springs are also shown. Engineers' small tools and steel castings displayed will be referred to later.

Lee of Sheffield, Ltd., on Stand D.528, show a selection of bright steel bars, cold-rolled steel strip, stainless strip and wire, together with a selection of articles made from stainless steel.

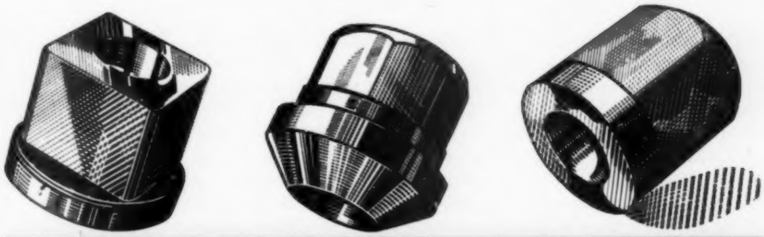
The Staveley Coal & Iron Co., Ltd., on Stand B.517-46, in addition to ranges of foundry and forge pig irons, Bradley refined irons, cylinder irons, malleable cold blast and alloy irons, display a wide range of their products. For many years this firm has specialised in the manufacture of spun cast pipes in both metal and sand moulds. Diameters of 2½ in. to 7 in. are available from metal moulds in 12 ft. and 18 ft. lengths, while sand spun pipes are available 4 in. to 24 in. diameter in 16 ft. lengths. In addition vertically cast pipes, to British standard specification, are also produced. Socket and spigot specials of all types are made for use with the above pipes, and the pipes may be concrete lined or bitumen coated. Flanged pipes, flexible joints, and pre-cast lead joints, are also specialities, and among the exhibits are included a range of chemicals, such as ammonia products, coal tar products, acids, bleaching powder, caustic soda, soda products and salt.

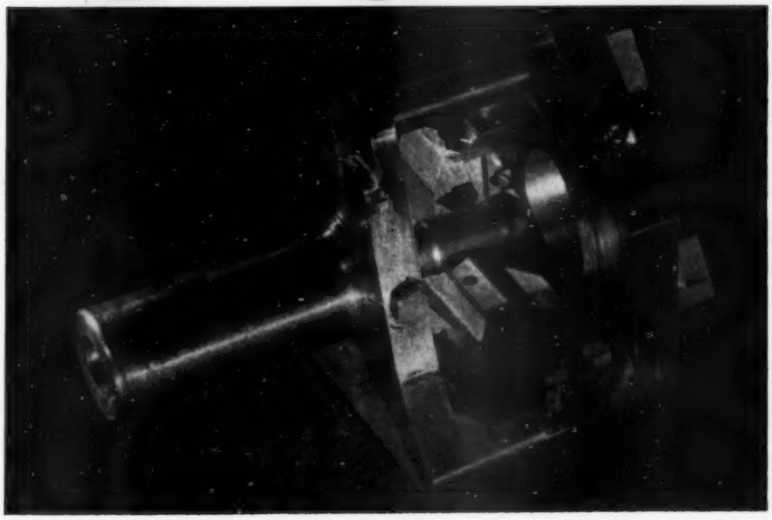
Stewarts & Lloyds, Ltd., and subsidiary and associated Companies exhibit a wide range of products. They have three stands: Engineering group, D.511/408, which is a reception stand, staffed by the Company's representatives; a building group, B.404; and outdoor exhibits, D.outdoor, which comprise a tubular steel construction, 81 ft. × 40 ft., constituting an exhibition hall including such products as: steel tubes for the conveyance of steam, gas, air, water, oil and sewage—both mains and distribution pipes; large diameter tubes—up to 72 in. dia.—for service mains, showing various protective linings and sheathings in common use; tubular steel coils; examples of oil country tubular goods and artesian well-boring equipment; coal-mining equipment, including controlled yield supports and a variety of joints and couplings; foundry and basic pig irons; iron and steel castings; and examples of steel and tube-works by-products. In addition to the foregoing, a number of show-cases and photographic enlargements are displayed, showing the world-wide contribution made by Stewarts and Lloyds to agriculture, municipalities, railways and the shipbuilding industry.



Courtesy of Protolite, Ltd.

Cemented tungsten carbide sleeved slitting cutters.





The Chatwin polygon box showing some typical shapes produced by it from round stock.

Metals and Alloys

Both the ferrous and non-ferrous metals industries depend upon supplies of metals and alloys of reliable quality and composition, and the display of MUREX, LTD. on STANDS D.247 AND 144 is of special interest. Part of one of the stands illustrates, by means of photographs, different aspects of the manufacture of carbon-free ferro alloys, pure metals and non-ferrous alloys. Alloys and metals displayed include: Ferro tungsten; tungsten metal powder; tungsten carbide; tungsten salts; ferro vanadium; ammonium meta vanadate, vanadium pentoxide and other vanadium salts; ferro molybdenum; molybdenum metal powder (99·8% Mo); molybdenum carbide; molybdenum salts; chromium metal; fire-refined copper, in grades containing minimum 99·88%, 99·7%, and 99·5% copper respectively; ferro titanium; titanium aluminium; nickel titanium; titanium copper aluminium; manganese metal; refined ferro manganese, manganese copper and other manganese alloys; aluminium powder. A speciality is made of aluminium hardeners of which a large range is produced, including the following: Manganese aluminium, titanium aluminium, silicon aluminium, chromium aluminium, tungsten aluminium, molybdenum aluminium, vanadium aluminium, zirconium aluminium, niobium aluminium and tantalum aluminium. Other metals and alloys made include: ferro chrome, " Eel " anti-friction metal, nickel titanium, nickel aluminium, nickel silicon, ferro niobium (columbium), with a tin content of as low as 0·5% maximum, tantalum metal, ferro boron, manganese boron, boron copper, cobalt metal powder, cobalt copper, and cobalt aluminium.

Murex have lately developed a process for the manufacture of aluminium-nickel-cobalt permanent magnets by powder metallurgy methods. Magnets made from these materials have been hitherto only as castings. These alloys cannot be fabricated by rolling, forging or any other similar process and owing to their hardness they cannot be machined. In addition the Protolite range of Murex metallurgical products has been appreciably extended during the past twelve months, and a fully representative display of all current productions is on view. One of the newest features last year consisted of cemented tungsten carbide sleeved rolls for rolling strip and flattening wire. In the meantime, carbide sleeved-slitting cutters involving a somewhat similar production technique have been added, and both they and the previous rolls give promise of ever-increasing use. Another new arrival in the list of Protolite products is to be found in split steady bushes and feed fingers with cemented tungsten-carbide inserts, greatly minimising the wear and thus increasing the efficiency of the automatic machines on which they are used.

Rolling Mill Rolls

The enormous outputs demanded during the recent war imposed increasingly severe duties on rolls, and the metallurgist and research worker were called upon to do the seemingly impossible. They had to combine the properties of toughness and hardness, wear resistance and heat resistance, and similar opposed characteristics. Among the many qualities of cast iron rolls produced in the foundries of THE BRITISH ROLLMAKERS' CORPORATION, LTD., STAND D.229, are found types to suit practically every known mill requirement. Compared with rolls of the last decade hardnesses have been doubled and rolling outputs increased by 300%.

The most outstanding achievement during the war years was the development of the super-hard cast roll and its application to the manufacture of light alloy sheets for aircraft construction. In the immediate post-war years and to-day a similar type roll has found increasing application where roll metals having superfine

finishes are desired. To-day, British rolls equals, and often excells the U.S.A. rolls in quality, in fact, some users of rolls equipped with American mills, express a preference for the British roll.

A further achievement of this Corporation was the development in this country of an entirely new type of alloy roll designed to satisfy the exacting conditions of the modern wide continuous strip mill. These mills call for speciality type rolls hitherto unknown in this country, and although there was no parallel experience on which to draw, suitable qualities were evolved, their ultimate performance exceeding all expectations and proving superior to the contemporary American types.

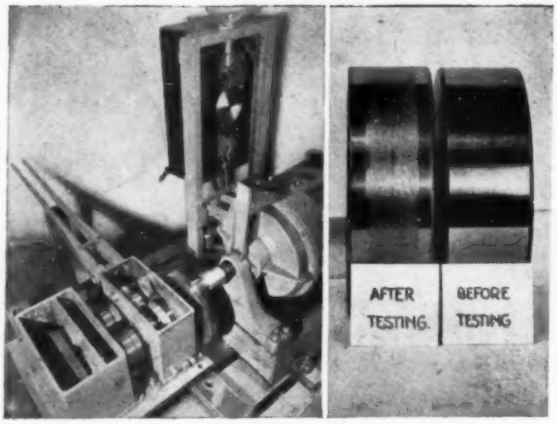
The call for speed in rolling made a change of bearing design in certain mills imperative, and the application of roller bearings and force feed lubrication created a demand for specially machined necks finished and ground to extremely fine limits. The shops were re-equipped to meet this demand, and now the most unconventional types can be supplied.

Examples of a wide variation of the Corporation's products are shown, in addition, comparisons in the structures of the old and new types of rolls are clearly seen with the aid of a microscope.

Tools and Tool Steels

Developments in cutting tools are considerable, but only a few typical examples among the many exhibits in this field can be given here. A comprehensive display of small tools and tool steels by English Steel Corporation, Ltd., Stand D.623 includes four new developments, all of which are protected either by patents or patents pending. One of these developments is that of a new type "Vickers" patent adjustable machine reamer, suitable for reaming "blind" and "through" holes to a very high degree of accuracy. It consists only of five main parts—arbor, cone bolt, body, micrometer nut graduated in thousandths of an inch with sub-divisions, and specially toughened 22% tungsten high-speed steel blades, the latter being slightly inclined to the axis to prevent any trace of chatter during reaming. Another reamer developed is an adjustable hand reamer, manufactured with either five or six blades and suitable for "through" holes. The improvements lie mainly in the method of securing the ends of the blades and in the incorporation of a micrometer adjustment nut which enables the reamer to be instantly adjusted to fractions of a thousandth of an inch. A third reamer development is that of the floating two-bladed type. This incorporates a very simple adjustment of the blades, enabling the reamers to be set to any desired size to within tenths of a thousandth of an inch accuracy. The remaining new development is that of the inserted blade milling cutter, which incorporates a very easy adjustment to the blades, and by the special design, the blades can be positively locked in any desired position.

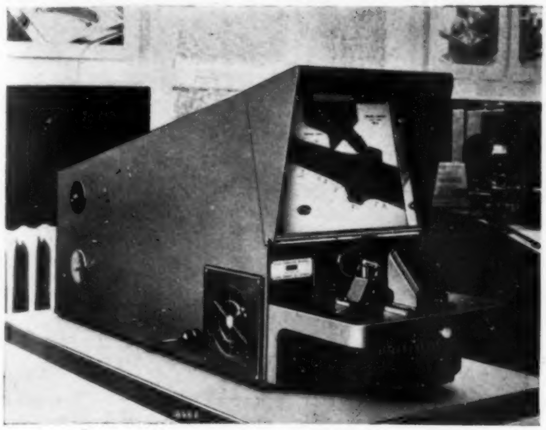
Edgar Allen & Co., Ltd. are exhibiting a full range of their special tools and steels, including double-ended boring bar cutters, various types of deposit welded form tools, high-speed steel milling cutters, key-seating tools, and punches for hot punching. Probably the most interesting exhibit is that which shows the deposit welding of high-speed steels such as 10/12% cobalt super high-speed steel, 18% tungsten high-speed steel, alloy steels and high carbon steels, etc. These exhibits are manufactured by this company's patent process and marketed under the trade name of "Athyweld." The primary object of the Athyweld process is to put a relatively small piece of the right steel in the right place. This is often extremely advantageous from the point of view of economy, and in other instances from the point of view of greatly increased strength. The exhibits show that the steels welded are those generally recognised as unweldable, but development and research have enabled the inherent difficulties with these materials to be overcome. A range of special tools welded by this process are on view, many of which are so complicated that the usual method of production would either be impossible or extremely difficult and very costly.



A 6 in. David Brown self-aligning disc machine for testing gear materials and lubricants. Right: Nickel steel discs, before and after failure by scuffing, following a lubrication breakdown.

Physical demonstrations of tungsten carbide tooling are the key-note of the display by A. C. Wickman, Ltd., Stand D.416. Experience and improved technique have shown that few materials can offer serious resistance to carbide cutting tools, from the hardest steels to the abrasive ceramics, etc., and in addition an important and gratifying result of their use is generally a startling increase in production per-man-hour leading to immediate substantial savings in costs. Proof of the inherent wear resistant and cutting qualities of Wimet tungsten carbide is available on the stand where may be seen a vitrified abrasive wheel, cut and formed by a Wimet standard cutting tool. The tool itself is available for inspection together with two high-speed steel tools with which was attempted the same test, but with disastrous effect on the tools. High-speed deep slot milling are demonstrated with Wimet cutters under conditions as near as possible to those obtaining in the average machine shop, and the slotted billets are then turned to demonstrate the efficiency of Wimet cutting tools on interrupted cutting applications.

Although primarily developed as a cutting tool, the application of tungsten carbide to drawing dies is an important function of the material. While cutting and drawing applications constitute an important field for its exploitation it is, however, also being increasingly used as a wear resistant for such widely diverse applications as thread guides for textiles; tabletting tools for food and pharmaceutical products; press tools and dies, etc., in many cases providing a life hundreds of times greater than the materials which it replaces.



Courtesy o Alfred Herbert, Ltd.

The Hilger production projector.

Many visitors to the Exhibition will be intrigued by the Chatwin polygon box on Stand D.405/304 occupied by J. BROCKHOUSE & Co., LTD. and its twenty-five subsidiaries. This is a lathe fitment which calls for a first-class service in the supply of thread milling cutters. By using these tools the danger of torn threads or broken taps is overcome, the finish of components is considerably improved, and the size required is always under control. Chatwin's offer two grades of thread milling cutters—the special finish and ground thread. Hexagon, octagon, square, or other shapes can be formed on a round bar and drilled and finished in one operation, ready for parting from the bar—that's what the Polygon tool box can do. It effectively cuts costs by the operations eliminated on a job of reasonable proportions; this polygon tool box speeds up production. This is only one product of an impressive range which, in addition to tools, includes iron and steel castings, drop forgings, metal sections including cold-rolled sections, and industrial and domestic heating equipment.

DELORO STELLITE, LTD. are showing a complete range of the new Grade 100 "Stellite" high-production tools for machining metals, wood, plastics, etc. Machining demonstrations are being given and the depositing of Stellite by welding is being carried on throughout the duration of the Exhibition. To demonstrate the heat and shock resistance of Grade 100 Stellite cutting metal a tool heated red hot is being shown taking an intermittent cut.

Iron Powders

Two types of iron powder are shown by GEORGE COHEN SONS & Co., LTD., which are sold under the trade name "Sintrex," they are electrolytic iron and grey cast iron. The former is supplied either annealed or unannealed in a wide selection of mesh gradings and is packed in sealed tins in which it can be stored indefinitely without deterioration. A special Laboratory of the 600 Group of Companies is engaged solely on research into problems relating to iron powder metallurgy and investigations into new applications of iron powders. The cast-iron powder is supplied in a variety of mesh gradings to suit individual requirements and is packed in steel drums.

Malleable Iron Castings

The quality of British malleable castings has improved over the war years, and it has been realised for some time that revision of the 1927 standard specifications was long overdue. In view of the considerable improvements in the quality of malleable cast iron, the old specifications not only became unrepresentative of the product, but were misleading to designers and prospective users of the material. A Committee was formed and as a result of its work new standards B.S.309, 1947, for whiteheart, and B.S.310, 1947, for blackheart, were published by the British Standards Institution. These new specifications clearly indicate to the designer the range of mechanical properties now offered by malleable cast iron. A summary of specification requirements is given in Table I.

These new British standards compare favourably with those in force abroad. Apart from the mention of an optional bend test in the Argentine specifications, the British standards are alone in specifying this test, which is included mainly as a safeguard against excessive phosphorus content. As an alternative to the acceptance of the bend test, the purchaser may obtain an assurance from the manufacturer that the phosphorus content shall not exceed 0·1% for whiteheart and 0·2% phosphorus for blackheart.

Among the exhibits of malleable iron castings is one of the largest producers of blackheart in the country, HALE & HALE (TIPTON), LTD. Castings for a wide variety of trades and industries are on view with mechanical properties in accordance with the new B.S.310, 1947, together with a display of colliery devices such as wedge pit props, screw props, etc. Special interest will be shown in the special purpose material known as "Permalite" developed by this Company, which is allied to the malleable iron family and has a tensile strength of 33–35 tons/sq. in. in comparison with 20–24 tons for good quality blackheart. This material is shock-resisting and has good elongation which is indicative of ductility not usually associated with high-duty cast irons.

FOLLSAIN METALS, LTD. are sharing STAND D.326 with their associated companies the Wycliffe Foundry

TABLE I MALLEABLE CAST IRON SPECIFICATIONS: SUMMARY OF REQUIREMENTS.

	Grade, Type, Designation, etc.	Diam. of test bar, in.	Minimum Tensile Strength, Tons/ sq. in.	Yield Point, Tons/ sq. in.	Elongation, per cent.
British B.S. 309 and 310 (1947)	Grade 1. Whiteheart. Sections over [illegible]-in.	0·564	22	12	4 on 2-in.
	" " " [illegible]–[illegible]-in.	0·357	20	11	6 on 1·25-in.
	" " " under [illegible]-in.	0 252	20	11	6 on 1·0-in.
	Grade 2 " Sections over [illegible]-in.	0·564	24	13	8 on 2-in.
	" " " [illegible]–[illegible]-in.	0·357	22	12	10 on 1·25-in.
	" " " under [illegible]-in.	0·252	22	12	12 on 1·0-in.
	Grade 1. Blackheart. All sections	0·564	18	10	6 on 2-in.
	Grade 2. " "	0·564	20	11	10 on 2-in.
	Grade 3. " "	0·564	22	12	14 on 2-in.
	(Bend	tests are also	included).		

& Eng. Co., Ltd., and Varatio-Strateline Gears, Ltd., and show examples of their E.V.H.1 heat-resisting nickel chrome steel, notably carburising boxes, trays, hearth grids, burner nozzles, superheater tube supports and furnace pots; also superheater elements, pyrometer sheaths, cyanide pots, carburising boxes, etc., in mild steel treated by their "Penetral" process which renders mild resistant to oxidation for temperatures up to 1,000° C. The effect of this treatment is to increase the life of ordinary mild steel articles by approximately five to six times. In view of the present steel shortage this treatment is of particular interest. Various examples of castings made in C.Y. abrasion resisting alloy are also shown. This material lasts approximately three to five times longer than good chilled iron and compares very favourably with manganese steel although costing considerably less. Typical examples on show will be locomotive brake blocks, haulage surge wheel segments, liner plates for crushers and pulverisers, chute plates etc.

The Wycliffe Foundry & Eng. Co., Ltd. are showing various examples of blackheart malleable iron castings and of Wynite nickel chrome high-duty cast-iron castings.

Pressure Vessels

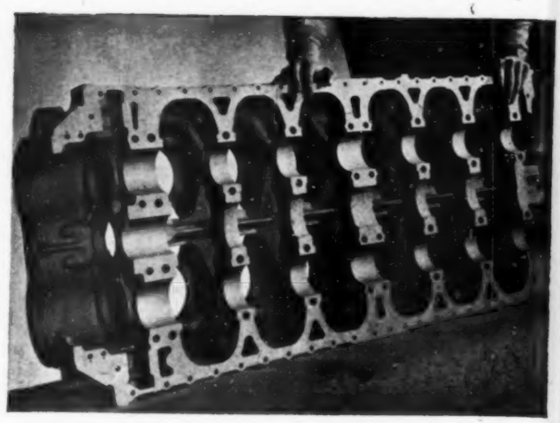
The Associated Companies of John Thompson, Ltd., occupying Stand D.521/418, show several scale models, as well as exhibits of their current production porgramme. They include a pressed boiler end in mild steel, together with a pressed vessel in stainless steel and a welded "Everdur" vessel; these last two exhibits representing new technique in this country. Scale models of complete boiler-house installations, one in this country and the other at Mekalla, Egypt, are shown, in addition to a welded boiler drum for a marine boiler. Samples of high-pressure pipework, special flanges, etc., are also included. This company specialises in the design, manufacture and installation of high-pressure pipework of all kinds, as well as the fabrication of pipework *in situ*, having a mobile X-ray plant for inspection.

Copper and Copper Alloys

Next to iron, copper is the most universally used of all metals and its uses have expanded greatly in recent years. This is readily understood when it is realised that of a total world-production tonnage during the last 100 years, one half was mined in the last twenty years and nearly one-third in the past ten years. British Commonwealth output has, in particular, shown a remarkable increase, and is now considerably greater than the United Kingdom consumption. It amounts to 25% of the total known world production. Northern Rhodesia alone contains about 32% of the officially reported ore reserves in the world.

Much progress has been made in the development and application of copper and its alloys and those seeking information and advice on the use of these materials should visit Stand D.230 of the Copper Development Association where exhibits are housed in a decorative structure built up of polished copper sheet and polished nickel silver, brass and gilding metal strip. Two large semi-circular columns, faced with polished copper sheet, and the Association's symbol in copper tube, are particularly striking features.

Exhibition panels on the stand illustrate the production and fabrication of copper and their applications in engineering, electrical engineering, building and the



Courtesy of High Duty Alloys, Ltd.

A cylinder block, weighing 191 lbs., sand cast in "Hiduminium" RR.50 for the "Napier Sabre" engine.

chemical industry. A number of excellent examples of fabricated products are shown, notable of these are four metallurgical panels which display unusual specimens of copper in fabricated forms—copper foil, a deep spinning, an example of electro-forming and woven-wire gauze. The copper foil is 0·0005 in. (half a thousandth of an inch) in thickness and 6 in. wide, and its production by cold rolling, in commercial quantities and to exacting requirements, is a technical achievement of a high order. The foil is valuable for electrical and other applications. Another typical example is a master control valve in gunmetal from an hydraulic bulkhead door system, shown as a typical example of the ease of casting which characterises copper alloys, together with other such properties as high strength, freedom from porosity and good machinability. The valve in question is for a working pressure of 700 lb./sq. in.

Imperial Chemical Industries, Ltd., Metals Division, have evolved special methods for manufacturing tubes in the new copper-nickel-brass alloy, and a sea-water intake tube (16 ft. × 8¼ in.) in the alloy is among their exhibits on Stand D.409. This new alloy (B.N.F.M.R.A. Patent No. 577065) has a very high degree of resistance to both corrosion and erosion, and is recommended for all non-water pipe-lines where unalloyed copper tubes are prone to these forms of attack. Tubes made of it can be bent and flanged by any coppersmith, and are available in a wide range of sizes from ¼ in. up to 12 in. diameter.

An "Alumbro" (aluminium brass) tube, 10 ft. long, $8\frac{7}{16}$ in. diameter and $\frac{1}{8}$ in. thick, is also exhibited. Prolonged research work and field tests have proved this alloy to be very suitable for use in various forms of heat exchangers for oil equipment and similar application. "Alumbro" tubes are particularly resistant to corrosion, and retain their strength to a marked degree even at temperatures in the region of 400 ° C.

A particularly interesting exhibit is the accelerated corrosion and erosion testing apparatus developed by I.C.I. Metals Division for evaluating the corrosion resistance of various alloys for use in condensing plant.

Brass, bronze, copper and other non-ferrous metals and alloys in rod and bar form, are the principal products of The Delta Metal Co., Ltd., shown on Stand D.311, and these form the raw materials used by practically

Courtesy of Aln.in, Ltd.

Some structural details of a 60 ft. roof truss in aluminium alloy.

every one of the engineering, electrical and allied trades for the production of innumerable varieties of machined parts and fittings. Although bars of plain round, square, hexagonal and flat sections form the bulk of this company's rod trade, the manufacture of extruded shaped bars of almost every conceivable profile, and ranging in size from ⅛ in. to 8 or 9 in. or more in breadth, is an ever-growing feature of its production. The use of specially shaped bars, which had grown enormously during the period between the two wars, and which was naturally restricted from 1939 onwards to production requirements for the services, is again making further strides, and the many hundreds of examples of strange and diverse shapes to be seen on the stand, represent only a very small fraction of those available to the manufacturer, who is further able, in many cases, to have purpose-made shapes produced to his own requirements, thus eliminating much preparatory machine work.

The production of high-grade castings, stampings, forgings and bar in special bronzes and nickel base alloys, is a speciality of LANGLEY ALLOYS, LTD., of Langley, Slough, Bucks., and their exhibits are worthy of inspection. The quality of their materials has earned a high reputation, and allied to this, is their comprehensive technical service which ensures that the correct material is specified for any particular design or application. Realising that the choice of materials is one of the most important aspects of design, Langley offer their services for advice to designers and engineers in all sections of industry.

The works and plant are modern and, as would be expected, in view of the nature and quality of the products, there is strict laboratory supervision of all materials and processes throughout the various stages in the works, while research is constantly carried out to develop new alloys with even more desirable characteristics and performance.

The ranges of materials manufactured find application in the marine, electrical, automobile, aircraft, chemical and general mechanical engineering trades and textile, food and oil-refinery processes.

"Hidurax" aluminium bronzes possessing excellent physical and mechanical properties have been especially developed for use in contact with sea water and are highly resistant to corrosion and abrasion, besides having high-fatigue values. Exhibits in these alloys include: Castings of pump impellers, valves and fittings, forged fittings, pump spindles and valve seats.

In the electrical field this firm has developed materials of great strength and high electrical conductivity for applications where these properties are essential. A typical example of these materials is their "Hidurel 6" which is a precipitation hardened copper-chromium alloy with a tensile strength when forged of 21–25 tons/sq. in. and 28–38 tons as drawn bar, the electrical conductivity being a minimum of 80%. In the cast form the tensile strength is 18–22 tons/sq. in. without any loss of conductivity. A further most desirable property of this material is that the advantages over pure copper are maintained at elevated temperatures and constant re-heating in service does not affect the properties when normal temperatures are once more attained.

The Langalloy "R" series nickel-base alloys are the latest development of Langley research in a field previously met from the U.S.A. These nickel-chromium-molybdenum and nickel-silicon alloys possess high resistance to strongly corrosive agents such as hydrochloric, sulphuric, nitric and phosphoric acids. They consequently have wide applications in the chemical industry and related fields such as textiles, oil refineries, cellophane manufacture, and many others. Some indication of the resistance of these alloys to a wide range of corrosive media is shown in Table II and, while the service conditions obviously have important influence on the degree of corrosion resistance, it may be regarded as a useful guide.

A considerable range of non-ferrous tubes and fittings is shown by YORKSHIRE COPPER WORKS, LTD. on STAND B.725 and 634. This company produce tubes from 0·005 in. to 24 in. inside diameter. The stand is built in three tiers, the bottom one being panelled with copper tubes, aluminium brass condenser tubes, and cupro-nickel condenser tubes. On either side are seamless copper tubes up to 24 in. diameter. Copper tubes for underground water services, panel heating installations and other purposes are displayed in the form of coil

TABLE II.—LANGALLOY NICKEL ALLOYS.
CHART OF CORROSION RESISTANCE.

	Langalloy 4 R.	Langalloy 5 R.	Langalloy 6 R.
Acetic Acid—cold	A	A	A
Acetic Acid—hot	B	A	A
Ammonia	A	A	A
Ammonium Nitrate	C	A	B
Ammonium Persulphate	D	A	D
Bleach Liquor	C	A	D
Bromine—wet or solution	C	B	C
Calcium Bisulphite	D	A	B
Calcium Hypochlorite	C	A	D
Chlorine—wet	D	B	D
Chromic Acid	C	B	D
Cupric Chloride	C	B	C
Ferric Chloride	D	B	D
Formic Acid	B	A	B
Hydrobromic Acid	A	B	B
Hydrochloric Acid—cold	A	A	B
Hydrocholric Acid—hot	A	C	C
Hydrofluoric Acid	B	A	B
Nitric Acid—cold	D	A	B
Nitric Acid <30%—hot	D	B	D
Nitric Acid >30%—hot	D	C	D
Phosphoric Acid—cold	A	A	A
Phosphoric Acid—hot	A	B	B
Sodium Bisulphite	C	A	B
Sodium Hypochlorite	C	A	D
Sulphuric Acid—cold	A	A	A
Sulphuric Acid <50%—hot	A	B	B
Sulphuric Acid 60%—hot	B	C	B
Sulphuric Acid 85%—hot	C	C	B
Sulphuric Acid, Concentrated—hot	B	D	B

A—Very good under most conditions.
B—Very good—suitability depends on conditions.
C—Some corrosion expected—use with caution.
D—Not recommended.

This Chart is intended to indicate a few typical uses of Langalloy nickel alloys. It MUST NOT be regarded as a firm recommendation.

tables. These tubes are supplied in 30, 45, and 60 ft. coils and are suitable for working pressures up to 200 lb./sq. in. (460 ft. head).

Tin Research

THE TIN RESEARCH INSTITUTE concentrates attention on four themes: the availability of tin, the Institute's functions, and details of two techniques developed and sponsored by this Institute. Since 1945 rcovery has got fairly under way and now the rate of production of tin in the world has already become equal to the present rate of consumption; admittedly today's consumption is restricted by Governmental controls in one or two big consumer countries, but the rate of rehabilitation of the mines makes it quite clear that, from now on, relaxations of these controls are bound to follow and there should soon be nothing to prevent a free market in tin.

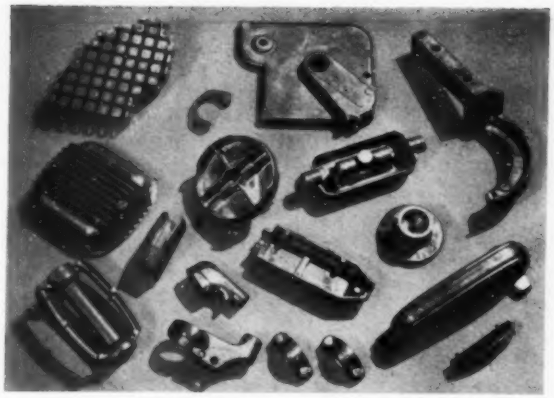
Tin's value as a priming on steel before painting is illustrated by a new display device with showers of artificial rain descending upon two model cars. The car with a tin coating only 50 millionths of an inch thick (about half as thick as the tin coating on an ordinary can) is seen to be free from rust, but the other car, without any tin, is a sorry contrast. This application of tin under paint is considered to have a promising future.

Bronzes with the strength of steel but not liable, as steel is, to rusting are something engineers should know about. How such bronzes can be made is illustrated in a model with a full-size crucible pouring molten bronze into a chill mould by the improved technique perfected at the Institute.

Nickel and Nickel Alloys

THE MOND NICKEL CO., LTD. show a wide range of products covering nickel-containing materials under four headings: high-temperature alloys, alloys with special expansion characteristics, alloys for the radio and electrical industries, and precious metals used in industry. Of particular interest are the high-strength materials, for use in the construction of the gas turbine, known as the "Nimonic" alloys. These are based on the 80/20 nickel-chromium alloy. In their development the first requirement was for an alloy suitable for use at 750° C. and "Nimonic 75" was introduced and provided the required properties. The design conditions were then materially altered to those of a highly-stressed turbine blade at a lower temperature of 650° C. Under these new conditions Nimonic 75 was not adequate, but for higher temperature operation, in the form of sheet in flame tubes, it has proved to be most satisfactory for the construction of the combustion chamber. Further research on blade materials resulted in the development of a new alloy, "Nimonic 80," having creep properties considerably higher than those of any other material then available. Since 1942, Nimonic 80 has remained the standard material for aircraft rotor blades in all-British jet engines. Other applications of this series of alloys are also shown.

Among the nickel-iron alloys are a series whose coefficients of expansion vary from practically zero to about 20×10^{-6} per degree C. Applications for these alloys are widely diversified and the main feature exhibited in this section is an apparatus designed to demonstrate the various deflections resulting from heating different types of bimetal strip designed for use for different temperature ranges and operating conditions.



Courtesy of High Duty Alloys, Ltd

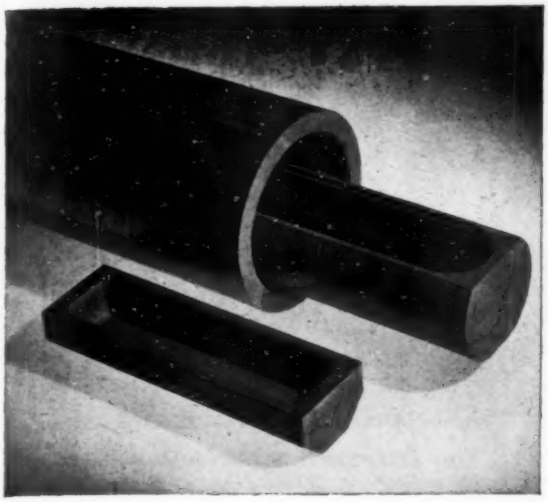
Group of pressure die castings, including door handles, bicycle accessories, cinema projector parts, food dicing and slicing machine components, and textile bobbins, made from "Hiduminium" alloys.

A recent development in alloys which have controllable coefficients of expansion is the development of the Ni-Span series of age-hardenable iron-nickel-titanium alloys. These can be fabricated readily and, with cold working followed by ageing, can be produced to have the required expansion and thermo-elastic characteristics with increased strength and hardness, making possible a much wider application of these alloys than was formerly possible.

Nickel-iron alloys may be divided into two main groups when considering their magnetic properties. One comprises the soft materials containing up to 85% of nickel, with high magnetic permeability at low field strengths and small hysteresis loop. These find their principal applications in the cores of high efficiency inductances and transformers used in communication circuits and in magnetic screens for sensitive instruments, etc. The other group comprises the permanent magnet alloys containing aluminium as an essential addition, with or without various other elements. Big reductions in size and weight for a given energy content have been brought about by the use of the newest materials, thus extending the scope of useful applications.

Aluminium and Its Alloys

The production and application of aluminium and its alloys, from a tonnage point of view, does not now reach the high levels of the years 1943–45; during the war years practically all the aluminium produced was allocated for war purposes and peace-time applications were reduced to negligible amounts, but the industry has made remarkable progress in adjusting itself to peace time conditions. To-day peace time applications far exceed those developed before the war and improved techniques developed during the war have been applied in casting, rolling, forging, extrusion, pressing, drop-stamping, heat treatment, welding and in finishing suitable alloys, to give the superior results now obtainable. Since the war the use of aluminium has been extended to purposes for which it was previously uneconomic in competition with other metals and materials. Special and improved equipment has made practicable the production of structural shapes, heavy plates, forgings, tubing and sections in a wide range of sizes. This Exhibition gives the industry an opportunity



Courtesy of Morgan Crucible Co., Ltd.

Morganite carbon tubes and boats for furnace works.

to bring to the notice of a very wide public in this country, as well as visitors from overseas, the wide and varied application of this relatively new material. Here it is only possible to review briefly some of these exhibits.

THE BRITISH ALUMINIUM CO., LTD., on STAND D.605, emphasise the acceptance of aluminium and aluminium alloys throughout almost every industrial field as high quality material of everyday use, available in the strengths and sizes required to meet, not only general manufacturing demands, but also the specialised requirements of structural, marine and other heavier engineering industries.

The special characteristics of aluminium—ease of fabrication, lightness and durability combined with strength—are enabling it to play an important part in helping industries to achieve new production targets. In plant, machinery and equipment, aluminium is assisting production by reducing deadweight and inertia, by increasing manufacturing speeds and payloads and by ensuring long life with reduced maintenance costs. The importance of aluminium manufactures in export markets is enhanced by high quality and attractive appearance.

With modern plant and equipment, backed by 50 years' experience of research and production, the British Aluminium Company is ready to meet the increasing demands of industry. Among this firm's exhibits are included examples of aluminium and aluminium alloy plate produced in material ranging from comparatively low strength high purity aluminium used for chemical plant, to the medium strength plate required by Lloyd's Register for aluminium alloys and the high strength plate used in structural engineering. Plate in the full range of alloys is available in sizes up to 18 ft. × 6 ft., and considerably larger sizes will soon be available, in certain alloys, in sizes up to 30 ft. × 6 ft. × ½ in., or proportionately thicker plate may be obtained for smaller areas within a maximum piece weight of approximately 1,500 lb. Plates up to 7 ft. 10 in. wide can also be produced in pure aluminium and the lower strength alloys within a maximum plate weight of 1,000 lb.

Available in the full range of alloys are sheets up to 18 ft. × 6 ft. in gauges from 20 s.w.g. to ¼ in. and coil 50 ft. × 4 ft. up to ⅛ in. Down to 20 s.w.g. sheets are available up to 6 ft. wide, down to 26 s.w.g. available to 4 ft. wide, and down to 30 s.w.g. available to 2 ft. 6 in. wide. Coiled strip is produced in different thicknesses from $\frac{3}{16}$ in. wide up to 4 ft. wide, and, although the maximum weight of coil varies with the width, coils of ½ ton weight are available in the widest strip.

Six thousand different shapes and sizes of section are available for general purposes ranging from a minimum weight of 0·05 lb. per foot up to the large sections. The ease with which aluminium and its alloys may be extruded and the relatively low cost of dies, also make the special designing of new sections an economic proposition.

Super purity aluminium is refined by a special process to a purity of 99·99% and possesses outstanding durability, ductility and response to processes for anodic and chemical surface treatments. It is used for many types of reflectors, for example, searchlight reflectors on H.M. Ships. Because super purity is the most ductile aluminium available it is increasingly popular in the building trade for flashings and weatherings. Among its many other uses may be mentioned particularly super purity foil for electrolytic condensers.

Special finishes include chequer plate for flooring and decking, whilst in thinner material fluted or pyramid matting finds uses ranging from vehicle floorboards to reflectors and decorative applications. Further attractive finishes may be chosen from the "Imprest" range of patterns, whilst for a fine-grain matt surface, satin finish sheet or strip is available.

NORTHERN ALUMINIUM COMPANY, whose products include most of the semi-fabricated forms of aluminium and aluminium alloys, on STAND D.629, emphasise the wide range of end uses of these metals. In recent years there have been many new applications of sheet, sections, tubing, wire, forgings and castings. The exhibit includes a representative selection of this Company's products, arranged on two low-level display counters. The main feature, however, will be a number of montage panels showing end uses, ranging from cranes and ships to dustpans and bottle caps. There are eight of these panels, featuring respectively building and structural engineering, all forms of transport, packaging, general engineering, electrical engineering, mining, farming, and domestic uses of aluminium.

Important new developments taking place in building and structural engineering are illustrated by drawings and photographs of aluminium bridges and excavators, scaffold tubes and ladders, roof trusses and corrugated sheeting, prefabricated school units, garden sheds, and greenhouses. Also shown on the panel are the 60 ft. high folding doors, constructed of Noral materials, of the Bristol Brabazon Assembly Hall at Filton, the roof glazing and immense windows of which are framed in Noral extruded sections. The giant aircraft itself appears on the transport panel, exemplifying Northern Aluminium's connection with the aircraft industry. Road and rail transport vehicles are represented in this section, which also indicates the growing use of aluminium in shipbuilding. Beer barrels, milk churns, and other metal containers from large acetic acid drums to toothpaste tubes and chocolate wrappings show the range of application of aluminium in the packaging field. One of the most important developments of recent years is the establishment of aluminium alloy fish boxes and

barrels, which keep fish much fresher and reduce rail charges.

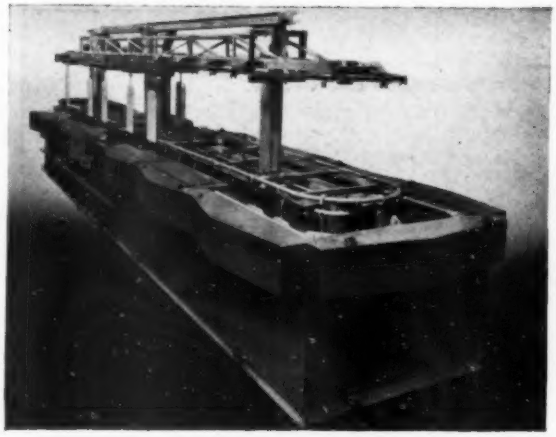
General engineering applications of aluminium alloys are many and diverse, and examples chosen for illustration include vibrating screens, filter presses, industrial trolleys, travelling cranes, ropeway systems, pulley blocks, machine tools. The long-established use of aluminium for overhead conductors in the Grid system is featured, together with busbar installations and more recent applications such as cast aluminium alloy housings for switchgear and motors, and grid towers and high tension substation structures built of aluminium alloy extruded sections. Future developments indicated include conduit installations, sheathing and armouring of power distribution cables, and conductors and armouring of heavy-current flexible cables.

Aluminium's part in agriculture is suggested in a composite drawing of a farm in which dairy and poultry equipment, carts, wagons, trailers, and various tractor- or horse-drawn implements, and even barbed wire and chain link fencing are of aluminium alloy. Light metal coal mining equipment is featured in the same way, an imaginative picture of a mine showing aluminium alloy skips, cages, mine tubs, jack props, roof supports, sylvesters, and suitable parts of face conveyors and electrical equipment. Domestic uses of aluminium are so numerous that the many items shown on the montage panel are necessarily a very incomplete representation.

High Duty Alloys, Ltd., with extensive plant at Slough, Redditch and Distington, manufactures cast and wrought components of all types in "Hiduminium" and "Magnuminium" aluminium and magnesium alloys. Many of these alloys evolved during the war years proved themselves time and again under the vigorous conditions imposed by aircraft requirements and, in consequence, were able to meet peace time needs with confidence. Each alloy has been developed to yield specific qualities under conditions which vary according to applications but all share the characteristics of lightness combined with high strength and corrosion resistance, ease of machining and fabrication and a bright, pleasing appearance. Among the newer exhibits shown by this Company include light alloy bobbins and accessories for the textile and wire drawing industries. High efficiency production methods and the fine dimensional tolerances achieved ensure almost complete uniformity of balance, making possible much higher running speeds for spinning, creping and doubling. This balance combined with lightness also reduces operating costs and vibration, increases payload and generally improves performance. Such bobbins can readily be dyed in a wide range of attractive colours which are used for the determination of yarn dernier by co-ordination of gauge with colour.

Rainwater goods, cast in a Hiduminium alloy, which offer many advantages, are shown. Their low weight, only one-third that of cast iron, makes them easy to handle and simple to fit with consequent savings in labour and transport overheads. This lightness is achieved without loss of strength, and risks of breakage either in transit or on site are reduced to a minimum. The fittings are not subject to fracture by blows or freezing conditions and their high natural corrosion resistance and pleasing appearance makes painting unnecessary in normal atmospheres.

Examples of components for pressure cookers, electric fires, washing machines, food manufacturing accessories, moulds for the manufacture of hot water bottles, are displayed. Also on view is a comprehensive range of components used in cycle production. Examples of cast cylinder blocks and pistons, cast and forged connecting rods, brake cylinders and fittings, used in automobile and general engineering, and such components as delivery forceps, plaster shears and camera cases used in the making of surgical and scientific instruments.



An Efco "Udylite" automatic plating plant.

Aluminium alloy construction for building has now been fully established. During the last twelve months enormous strides have been made. On Stand 721, in the Building Section, Almin, Ltd. (Associated Light Metal Industries) feature the products of its associates: Southern Forge, Ltd., with extrusions, tubes, forgings; and Structural and Mechanical Development Engineers, Ltd., with buildings, components, engineering structures, etc., in aluminium alloys.

Models of portable and permanent buildings in aluminium alloy are on view. The former comprise buildings made from standard bays 9 ft. long × 38 ft. wide, which have now been designed and constructed by Structural & Mechanical Development Engineers, Ltd. Standard buildings, 72 ft. × 38 ft. (composed of eight 9 ft. bays) are now on their way to E. Africa for the Groundnuts Scheme for storage of the nuts and equipment. These buildings are erected in 10 hours by eight unskilled men. They are demountable in a few hours for removal to a new site. The same design of building can be erected for permanent use by employing brick or concrete walls.

Aluminium alloys are completely rust and corrosion proof and require no painting or treatment. The metal is used in these buildings without any sort of protection and yet requires no maintenance. It is also termite and vermin proof which renders it particularly suitable for use in hot climates. Also in hot climates, the high reflective values of the aluminium roof and sides maintains the interior of the building at a low temperature.

Other applications that are displayed or demonstrated by photographs or drawings, include: Office, hospital and domestic partitions; garages; greenhouses and horticultural buildings; adjustable hospital beds; food serving counters for shops; and electric conduit tubing. Greatly increased use is also being

Courtesy of Schori Metallising Process, Ltd.

Zinc sprayed girders of Weston-super-Mare piers.

made in other fields, e.g.: Shop fronts and shop fittings; windows; doors and door frames; railings; ornamental gates; rainwater pipes and gutters, etc.; scaffolding, etc.

Magnesium and Its Alloys

To the layman the fact that a great percentage of the magnesium produced in this country during the war came from sea water would be received with some surprise, but Dr. F. A. Fox, discussing the subject in a recent Science Survey broadcast, did much to clarify the position. Salt, of course, as he pointed out, has been prepared from sea water since the dawn of history, but apart from salt, till quite recently the sea has refused to yield up its vast store of raw materials. One cubic mile of sea water contains over four million tons of magnesium and most of the record war time production did come from the seas.

Sea water contains most things, and that includes about 0·14% of magnesium chloride. In September, 1939, the extraction of magnesium from sea water was well established in this country, and although Britain had stocks of imported ores, which were naturally used up, it can be estimated that three-quarters of her war-time magnesium production came from sea water. Large extensions of her magnesium producing plants were planned and built and by the end of the war nearly 3,000 tons a month was being produced instead of the 350 tons during the whole of 1939.

Lightness is of course the main attraction of magnesium, especially for the moving parts of machines in which dead weight is so much waste. Then lightness has hidden as well as direct advantages. For example, the wear of other parts is often reduced if a working part can be lightened, or supporting parts can themselves be reduced in weight. But lightness has no value without strength, and a considerable part of the total effort of development has gone into the question of alloying the magnesium in the best way to obtain the highest strength.

The principal metals with which magnesium is alloyed are aluminium, zinc, manganese, and more recently, zirconium. Aluminium is sometimes added in amounts up to 10% and it is fortunate that this successful alloying agent is itself a light metal. The magnesium alloys can be cast, forged, rolled, extruded, and in short, handled according to all the accepted processes for engineering materials, although sometimes rather special techniques are needed. The magnesium alloys have about the same strength as many aluminium alloys so they are used where extra weight saving is essential. Magnesium alloys are at least as resistant to corrosion as ordinary steel; this means that for most uses they must be painted in the same way as most steel. In practice it is only a very few environments that magnesium alloys must not be used.

Some exhibits of applications of magnesium alloys have been mentioned previously, but particular attention is directed to the exhibits of F. A. Hughes & Co., Ltd., who are showing Elektron magnesium sheet, extrusions and castings, together with Elektron prototype constructions. Considerable interest will certainly be shown in the new range of magnesium-zirconium alloys on view, because of their outstanding properties.

Silver Solders and Brazing Alloys

The Sheffield Smelting Co., Ltd., exhibit a wide range of their products at both London and Birmingham, but on Stand D.731 at Birmingham is devoted to the industrial uses of precious metals. Silver solders and brazing alloys form another important section. They and other materials are marketed under the registered name "Thessco." Considerable strides were made during the war to produce solders of the physical characteristics required by the Air Ministry and the improvements attained will be found of great value to present day industry.

Among other items shown are electrical contacts for which there is a growing demand. These are made of pure metals and alloys, bi-metal strip or silver in combination with hardening material. "Thessco" platinum-platinum/rhodium thermocouples for pyrometers and other platinum apparatus will form part of the exhibit. Another branch of work undertaken by this Company is the casting of non-ferrous alloys.

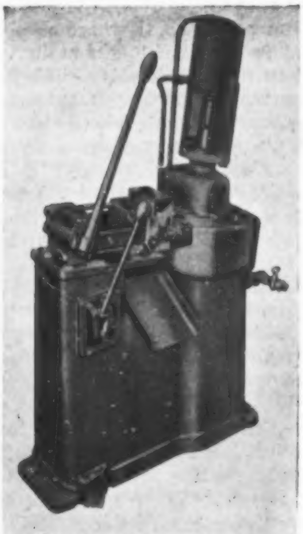
Ignition contacts, magneto contact breakers, and coil ignition replacement parts produced by F. Claudet, Ltd., an associated company, are also on view, as also is a special type of liquid steel pyrometer made by Messrs. T. Land & Sons, Ltd., of Sheffield.

Wire

Special sections of wire in all alloys are exhibited by John Rigby & Sons, Ltd., and many other firms who specialise in this product, including The London Electric Wire Company & Smiths, Ltd., and its associates, Frederick Smith & Co., The Liverpool Electric Cable Co., Ltd., and Vactite Wire Co., Ltd., who show, in the Electricity Section, on Stand C.320, a comprehensive display of bare and insulated conductors for all electrical purposes.

The "Lewcos" section contains insulated wires and strips, in numerous sizes, with coverings including cotton, silk, rayon, enamel, paper, asbestos and glass for use in power plants, coal cutters, switch-gear, radio etc., also copper braids and cords (both hand and machine plaited). Heat resisting wires and cables and "Glazite" connecting wires.

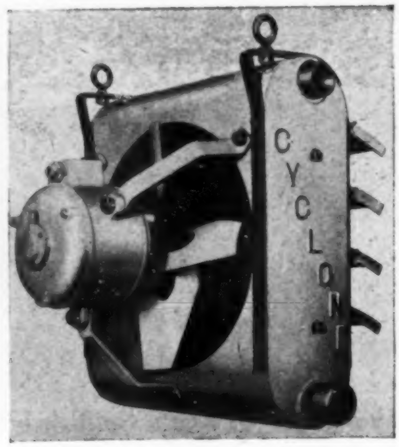
Fred. Smith & Co. display bare copper, cadmium-copper and bronze wires and bars—in sizes from 0·001 in. (finer than human hair) to 2¾ in. in diameter—strip for transformer windings and strand for power transmission and line wires, also trolley wires, commutator copper and copper alloys such as copper-chromium, tellurium copper and silver-clad copper wires and strips, bus bar



Courtesy Die Casting Machine Tools, Ltd.

Left—Die-casting machine with many improvements.

Laboratory Muffle Furnace



Cyclone unit heater by Matthew & Yates, Ltd.

copper, machined components in copper and copper alloys.

L.E.C. show rubber, cambric and paper insulated cables and flexibles for use in mines, quarries, factories, railways and houses, "Lecupler" (Regd.) bolted flameproof cable couplers, and the new L.E.C. electric vulcanizer for the repair of cable sheathing.

THE VACTITE WIRE Co. exhibit "Eureka" (Regd.) and nickel-chrome resistance wires and tapes, molybdenum rods, wires and tapes for electric furnaces, lamps and valves, also copper clad and Vac-steel wires.

Metal Spraying

SCHORI METALLISING PROCESS, LTD., have a complete demonstration unit showing the spraying of metal and plastic coatings by the powder flame spraying method. Articles which have been treated, and which are displayed, include: aluminium cinematograph projector cabinets sprayed with polythene instead of the more usual rexine covering, giving an attractive and durable protective coating; flame throwers sprayed with coloured polythene as a chip-proof camouflage finish to withstand arduous field service conditions; tubular electron aircraft seats sprayed with black polythene giving a pleasant durable coating; new "Astral" suitcases made of Birmabright also sprayed with coloured "pebble" polythene finish; cast aluminium wringer parts with pleasant green polythene finish.

The metal sprayed exhibits include: Car silencers, electric cooker boiling plate, collapsible fire escape ladder, metal casements, architectural ironwork, Calor gas cylinders, fire extinguisher bodies, glazing bars, deep drawn steel tank, impellor, bus-bar, filter press plates, X-ray tube, instrument box and undersized steel shaft.

In the field of chemical engineering, apart from our considerable activities in the protection of steel and cast iron plant, work has recently been done *in situ* on aluminium nitric acid tanks as a protection.

Die Casting Machines

A number of improvements have been incorporated in the M55A/HF die casting machine exhibited by DIE CASTING MACHINE TOOLS, LTD. These include a new poppet type valve incorporated in a panel on the side of the machine with a built-in safety valve. Valve seatings are removable for replacement without the uncoupling of any pipes. Both hand and foot valve operating mechanism are incorporated as standard on each machine so that it is possible to use hand or foot when and where required. Larger bore piping connects the valve and cylinder head, which, together with the larger ports in the valve enables the plunger to move at a greater speed. A separate cast iron die unit base

Continued on page 59

Modern Uses of Hard Metals

By H. Burden, B.Sc.
Brown Firth Research Laboratories, Sheffield

In recent years the manufacture of hard metals has been developed from relatively small scale production of a limited number of grades to a large industry capable of high outputs, using new methods of quality control and specially designed continuously operated equipment. This progress has been coupled with the thorough investigation of the properties of the hard metals and to-day hard metal products are not only more uniform and reliable in their properties and performance, but the grades available have greatly increased. An effort to classify the various grades, according to their composition and properties, and to show how they can be applied with advantage, is described by the author in " Alloy Metals Review" which is reproduced in this article in an abridged form.

Introduction

IN 1939 hard metal manufacture was almost a laboratory process and the use of the material limited. Only a limited number of grades were available and there was little chance of cross referencing these grades from different sources, because of variation in composition, properties and quality. This has been very largely changed. To-day manufacture has been developed from a semi-laboratory scale to that of a large industry using methods which are capable of great outputs, while new methods of quality control, coupled with the use of specially designed continuously operated equipment, has resulted in a product which is more uniform and reliable in its properties and performance. This development has resulted in an increased number of grades being now available and much information regarding their properties and use has been published from time to time. It is thought to be desirable, however, to indicate how the grades of hard metal at present available can be classified, according to their composition and properties, and how these properties fit them for the uses to which the material is put.

Although in the earliest work it was known that the properties of hard metals could be varied, it was only after years of research that the wide range of properties, which could be made available, was thoroughly appreciated. The importance of this work cannot be over emphasised, for the successful use of hard metal depends in the first place upon correct grade selection. It should be remembered that hard metal may vary in hardness over a range greater than that between lead and the hardest steel, while it may be brittle or have the toughness of a good tool steel.

Classification of Hard Metals

Hard metals generally have been divided into two main groups ; those which are intended for the machining of steel and those for use as cutting tools for materials other than steel. There is some overlapping, but the general classification holds good. The reason for this rather strange classification was the failure of the first hard metal developed, the tungsten carbide/cobalt group of compositions, to machine steel satisfactorily ; even though it performed excellently as a cutting tool on all other materials, under suitable conditions. It was found that when these compositions were used for machining steel a chip cavity rapidly formed in the top face of the tool, and, by its enlargement, created an excessive top rake immediately adjacent to the cutting edge, causing failure of the edge by breakage. This disability of the tungsten carbide/cobalt compositions was overcome by the addition of other carbides, notably titanium carbide, tantalum carbide and molybdenum carbide. Of these additions by far the most effective was found to be titanium carbide. The tungsten carbide/cobalt compositions, which were the first satisfactory commercial hard metals, showed such a desirable combination of properties that they are still the basis of all modern hard metals ; other compositions, so far tried do not give the same combinations of strength and hardness. The addition of titanium carbide to the tungsten carbide/cobalt compositions, to form the steel machining grades, weakens the material, but this effect has been minimised by careful research into the manufacturing technique.

Within the two main groups referred to above—i.e., the steel cutting group and non-steel cutting groups, further classification may best be made on the basis of two properties ; these are the strength and wear resistance. The strength is determined by means of a transverse rupture test, while the wear resistance is obtained from a hardness test, although, as will be seen later, tests of a more practical type often have to be carried out.

The graph shown in Fig. 1 shows the variation in hardness and cross breaking strength which may be brought about by variations in the cobalt content in the cobalt/tungsten carbide range of alloys. The hardness rises with reduced cobalt content, while the strength of the material rises with increased cobalt content. By varying the cobalt content, therefore, it is possible to make material of extreme hardness, but with low strength, or softer grades having high strength. Thus, a tool tip for machining glass or chilled iron would have a composition of, say, 4% cobalt, while a tip to be built into a rivet snap, wire flattening hammers, swaging dies or other tools, which have to withstand shock, would have a cobalt content of 13–20%.

The graphs shown would be more accurate if the curves were represented as broad bands, rather than as lines, for the properties of a composition of a given cobalt content can also be varied. The most important factors are the grain size of the hard metal and the carbon content. Generally speaking, variations in carbon content are not used intentionally to obtain variations in properties, for such practice is attended by serious danger of undue brittleness, but use is often made of differing grain size. Coarse grain size results in increased toughness, while fine grain size can give very high hardness values and, as might be expected, the use of fine grain sizes is more common in the lower cobalt content materials, where the aim is to produce the highest hardness. It is fortunate that in the case of the tungsten

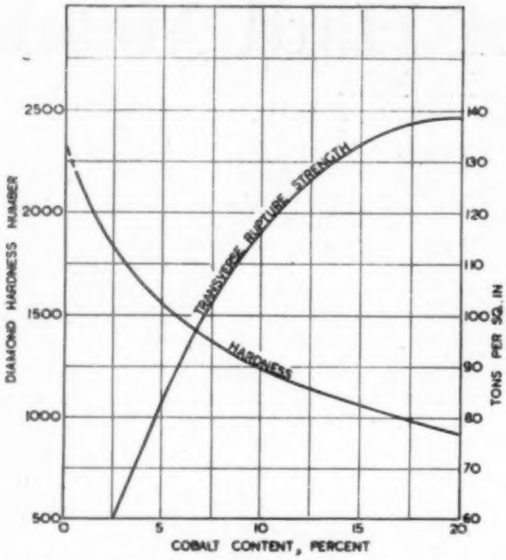


Fig. 1.—The effect of variation in cobalt content of tungsten carbide/cobalt alloys.

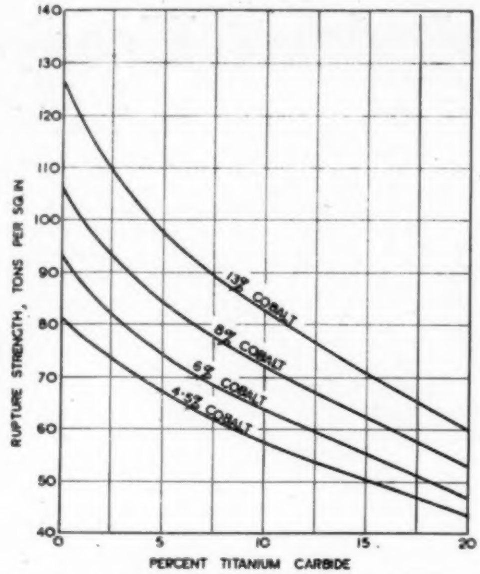


Fig. 2.—The effect of titanium additions on tungsten carbide/cobalt alloys.

carbide/cobalt compositions the physical properties give a good indication of the usefulness of the material as a cutting tool; for instance, the life of a tool which fails by wear can, with reasonable reliability, be correlated with the hardness, while the resistance of a tool to shock, imposed in the case of intermittent cutting, etc., can be correlated with the cross breaking strength.

The development of the steel cutting grades has involved the investigation of a larger number of factors. This has been actively carried out, and during the past few years the industry can well claim to have markedly improved their quality. It has already been mentioned that the modern steel cutting grades are generally obtained by the incorporation of titanium carbide in the tungsten carbide/cobalt compositions and that, apart from the effect of resisting cratering, which is the reason for the titanium carbide additions, it decreases the cross-breaking strength. This lowering in strength in the early steel cutting grades was often a serious handicap, but, fortunately, it has been found that it could be minimised so that by correct selection of composition, tools with excellent performance could be made for wide ranges of conditions. The strength of various tungsten carbide/titanium carbide/cobalt compositions is indicated in the graphs shown in Fig. 2. While the falling off in strength with titanium carbide addition is quite marked, it is nevertheless possible, by correct selection of titanium carbide content *and* cobalt content, to obtain satisfactory values.

A most interesting fact that has been brought to light in work on the titanium carbide grades is a lack of relationship between the hardness of the materials as determined by a penetration test such as the Diamond and Rockwell hardness tests and the wear resistance of the materials when used for machining steel. This has complicated the problem of developing these materials to a high degree and has necessitated the use of machining tests, which are lengthy and costly to carry out, as the only criterion of wear resistance of the steel-cutting grades. The addition of titanium carbide may have negligible effect or may slightly increase the Rockwell or Diamond hardness of the tungsten carbide/cobalt material to which it is added, depending upon various factors, but it has been found that the wear resistance, other things being constant, depends upon the percentage of titanium carbide added. Thus, in the case of the titanium carbide grades, wear resistance and strength can be varied in two ways, by alteration of the titanium carbide content and by alteration of the cobalt content. In each case the increase in wear resistance is only obtained by some sacrifice in strength, but the effect varies under different conditions and the choice of whether to modify cobalt content or titanium carbide content has to be determined for separate applications. The selection of suitable compositions, therefore, is more complicated in the case of steel cutting grades and particularly so in those cases where the tougher varieties are required.

The wear resistance or hardness, and strength of hard metal have been mainly considered, but many of the other properties and the way they vary with composition have been determined. Nevertheless, the combination of hardness and strength are major factors in determining the field of usefulness of these materials. In applying hard metals it is impossible to attempt to make different compositions for every job which comes along, although this would obviously result in optimum performance if cost need not be considered. On the other hand, a minimum number of compositions must be selected and made as standardised grades, to enable quantity production to be established, to minimise stocks which must be carried and to obviate as far as possible confusion in users' hands. These standard grades must cover the majority of jobs to which hard metals are to be applied as fully as possible and the judicious selection of these grades has an important bearing on the success with which hard metal can be used by industry. The problem is a two-fold one, in that the manufacturer of hard metal has to make the choice of a composition but the consumer can only reap the benefits of the use of these

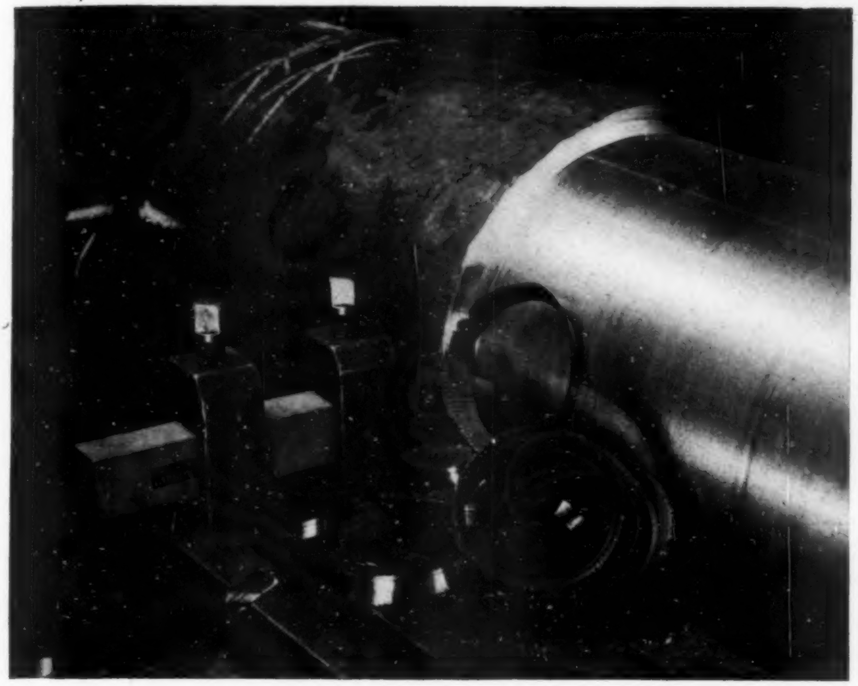


Fig. 3.—Machining a nickel-chrome steel (55–65 tons tensile) bomb forging, approximately 5 ft. long and 18–20 in. dia.

materials if he intelligently selects these grades for the different types of work with which he has to cope. It is very encouraging that in this particular aspect of the application of hard metal to industry good progress has been made. It will be gathered from these remarks that no single grade of hard metal is available which will cover all applications and there appears to be little likelihood of such a grade being developed in the future.

A considerable degree of standardisation has been effected during the past few years, and to-day, strong similarity exists in the properties of different brands of hard metal when they are classed according to the particular uses for which the grades are recommended. It is difficult to illustrate this point without introducing individual manufacturer's grade designations and analyses, but a hypothetical set of grade symbols is given in Tables I and II which set out the typical grades of hard metal now available in this country, together with some of their recommended fields of application. These tables show how the grades vary in composition and properties according to their use. Different brands do vary slightly, even for the same job, a variation which certainly all makers would support, but this does not interfere with the general classification.

The tungsten carbide/cobalt hard metals are available in, say, four grades: the first grade shown is the hardest, and least tough. It is used for the machining of very hard and abrasive materials which have not got very high strength, so that they cannot impose undue stresses on the tool. Examples, of course, are glass, chilled iron, slate, etc.; this grade can also be used to finish machineless abrasive materials.

The second grade is the commonly termed "general purpose grade" and is used for the machining of cast iron and non-ferrous metals, where no special problems are encountered. This grade is made in the greatest quantity and was probably the first to be made available commercially. It has a very desirable combination of strength and hardness, which enables it to be used for a wide range of applications distinct from cutting tools: for instance it is a very popular grade for wire-drawing dies.

The third grade is used where conditions call for greater strength, and is a popular grade for large drawing dies and for inserts to be fitted to machines for resistance of wear. It is also used for wood-working tools as these require a very keen edge, and the extra strength of this grade enables a keen edge to be held; a further use is for shears for metal cutting.

The fourth grade is the toughest of the range, and it will be noted that the hardness is about equal to or just in excess of the hardest tool steel. Nevertheless,

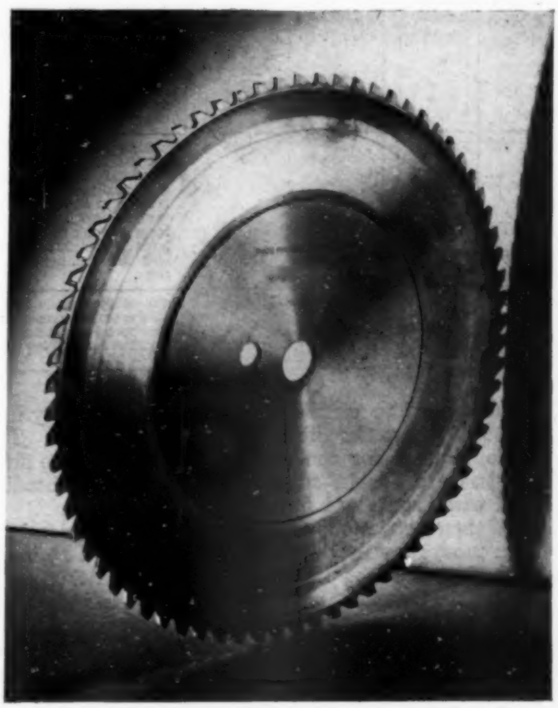


Fig. 4.—Hard metal tipped 32-in. saw for cutting riser heads from aluminium crank cases, roughly 13 × 44 in.; 1,300 castings were completed before reconditioning.

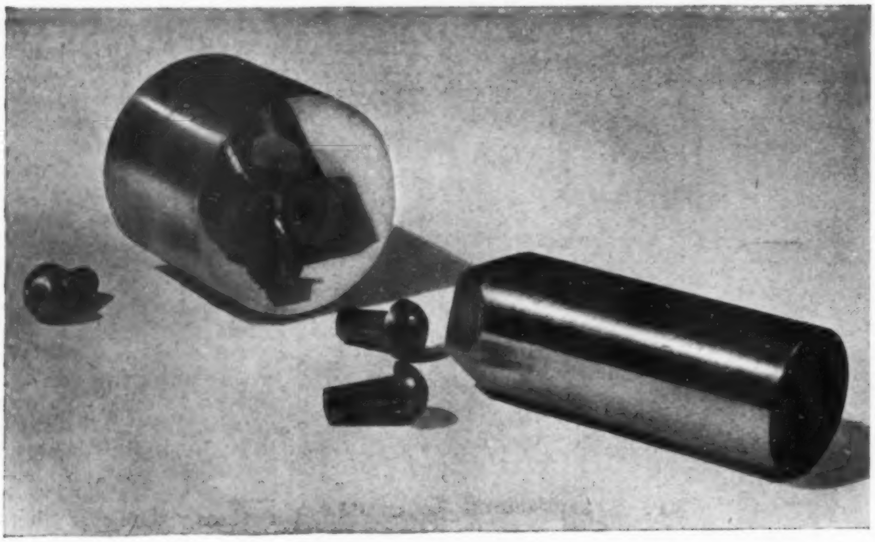


Fig. 5.—A hard metal hammer and heading die for making $\frac{3}{16}$ in. dia. rivets from aluminium and steel wire.

TABLE I.—TUNGSTEN CARBIDE/COBALT ALLOYS

Grade	Composition	Transverse Rupture Strength	Hardness Diamond Scale	Field of Application
1 ..	WC 95% Co. 5%	70 tons/sq. in.	1600	For machining very hard low strength materials—e.g., chilled iron, glass, slate, porcelain, synthetic substances. Also for fine cuts on cast iron and light alloys.
2 ..	WC 93·5% Co. 6·5%	100 tons/sq. in.	1500	General purpose grade for machining cast iron, non-ferrous metals, plastics, unless filled with abrasive fillers. For small wear-resisting parts not subject to shock. For wire-drawing dies.
3 ..	WC 89–91% Co. 9–11%	120 tons/sq. in.	1200	A tough grade, only used occasionally as a cutting tool for metals, and then under bad conditions. Used for keen-edged tools—wood-working tools. Used for large drawing dies, and for large wear-resisting parts; also for shearing applications.
4 ..	WC 84–87% Co. 13–16%	130–140 tons/sq. in.	950	Shock-resisting grade for percussive tools (hammers, etc.), for metal working, not suitable for cutting tools.

when applied to certain jobs, its life may be anything up to 50 times the life of the best tool steel. This grade is used for tools which require to have great resistance to shock, such as rivet snaps, cold heading dies, wire flattening hammers and such-like tools.

Of these grades the two latter are those which have been most recently developed, and it should be noted that they are not frequently used as cutting tools. Rather are they used for parts which have to resist wear.

Table II gives similar information regarding the steel cutting range of hard metals which are now available, but, unlike the tungsten carbide/cobalt grades, these grades are almost exclusively used as cutting tools. The grades shown vary in hardness and toughness in the same way as the tungsten carbide/cobalt grades; there are, however, two grades which may be said to fill the position of general purpose grades. The reason for this is that the "cratering effect" on tools caused by different steels has been found to vary considerably, and the titanium carbide content has to be adjusted to suit. In order to maintain the desired degree of toughness a corresponding adjustment in the cobalt content is necessary. The mild steels are found to show a greater tendency to crater than alloy steels, so that grade two is used as a general purpose tool for mild steel and plain carbon steels, while grade three is more successful on high alloy steels. This delineation is by no means clear-cut and instances are encountered in practice which do not conform with theory. In some cases manufacturers prefer to use a single grade to cover the general purpose range, for which a composition intermediate between those shown for grades two and three is used.

The toughest of the range of steel-cutting grades is again a recent development, and proved to be of great value during the war, when, as often happened, production had to be increased over that obtainable with tool steel on old or unsuitable machinery. In view of the fact that even when the best machine tools are available there will always be jobs, the nature of which impose undue shock or chatter on the tool, tough grades will always have an assured field.

In so far as machining is concerned, there are certain cases where the classification between steel-cutting grades and the non-steel-cutting grades falls down and apparently the "wrong grade" must be used. It is very difficult to give general reasons for this since it occurs in relatively few instances which are very dissimilar in character. There are, however, three cases where it is likely to occur and these are worth noting.

The first is in the machining of aluminium. Normally, one would expect to machine aluminium with the tungsten carbide/cobalt grades, but often it is found that a built-up edge forms with these grades, the aluminium swarf sticking to the tool. This is overcome if the steel-cutting grades are used. The second instance is in the machining of very rough steel forgings where removal of scale is the major factor, in such circumstances the titanium grades may be replaced by one of the tougher tungsten carbide/cobalt grades. In the third case it is found that when machining malleable iron it is profitable to run a test to determine whether one of the titanium carbide grades or one of the straight tungsten-carbide grades should be used.

Differences in the structure of malleable iron are a deciding factor in this matter.

The above remarks attempt to show how a very diverse range of grades are obtained, and it is interesting

to see the range of work to which they are now applied.

In examining the extending application of hard metals, it is found that the uses to which they can be put may conveniently fall into three classes. These are :—

1. Cutting tools.
2. Forming tools, as for instance, in drawing, rolling, etc.
3. Wear-resisting parts.

The application of hard metal to industry has reached its highest level in the first mentioned group, while very considerable progress has been made in their use for drawing and the forming of metals (this was in fact their first field of use). In the third group, however, it is believed that industry is only just beginning to realise to what extent hard metals, with their unusual properties, may be applied.

TABLE II.—TUNGSTEN/TITANIUM CARBIDE/COBALT ALLOYS

Grade	Composition	Transverse Rupture Strength	Hardness Diamond Scale	Field of Application
1 ..	WC 74% TiC 20% Co 6%	54 tons/sq. in.	1550	This grade is extremely hard and wear resistant It is designed for finish turning all classes of steel. Machining conditions must be good and the grade used at high speeds and fine feeds.
2 ..	WC 75–81% TiC 12–16% Co. 7–9%	65–75 tons/sq. in.	1450	This grade and grade 3 are general purpose grades. Grade 2 is more resistant to cratering and it is particularly useful on mild steel and low alloy steels. Used very effectively during the war as grade for the machining of shells.
3 ..	WC 84% TiC 10% Co. 6%	75 tons/sq. in.	1500	General purpose grade, particularly on alloy steel. While the properties of this grade are close to those of Grade 2 it will withstand more abuse.
4 ..	WC 79–86% TiC 5–8% Co. 9–13%	95–110 tons/sq. in.	1400	A heavy-duty grade for the rough machining of steel under bad conditions, particularly rough forgings and castings. Will successfully withstand intermittent cutting, and is used at relatively low speeds and heavy feeds.

Hard Metal Cutting Tools

The uses to which hard metals are put in the form of cutting tools are so varied that it is impossible to illustrate adequately what is now being done in a short paper, and only a few of the more interesting features can be noted. One of these, which has already been referred to, is the development of tougher steel cutting grades of hard metal. The reader will recall the early injunction to use hard metal tools with fine feeds and high speeds, and how often, in spite of this, the tools failed by chipping or breakage. It is interesting to compare such early recollections with a typical rough machining operation which was being regularly carried out towards the end of 1945. This was the machining of a 2,000 lb. bomb forging, see Fig. 3, which was carried out under the following conditions :—

Material : Nickel chrome steel, 55–65 tons tensile.
Feed : 0·080 in. per rev.
Speed : 100 ft. per min.
Depth of cut : Varying, but up to 1 in.

The forging was roughly 5 ft. long by 18–20 in. dia., and the tools would machine a forging completely without the necessity for re-grinding. This is a remarkable performance, particularly in view of the fact that the forging is very uneven and is covered with a very bad

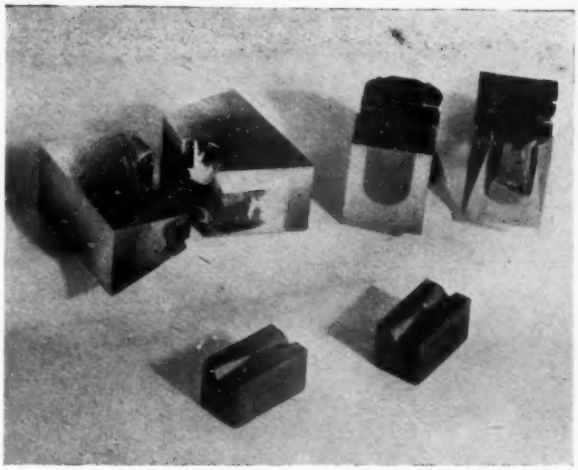


Fig. 6.—A set of hard metal swaging dies.

scale. The relatively low speeds at which the tools work is noteworthy, for there are many jobs which must be tackled where, for many reasons, the high speeds normally used with hard metals cannot be attained ; the use of the tougher grades now available enables hard metals to be applied to this type of work.

The success of hard metal tools when used under such arduous conditions depends very much upon the tool design. This is still further borne out in the design of hard metal tools in the recently developed fields of the milling of steel and in the machining of light alloys and plastics. In fact, it is true to say that while in the early development of hard metals the problems were chiefly those of the powder metallurgist, more recent progress largely depends upon the tools designer, who, while appreciating the very special characteristics of hard metal, can apply his knowledge of small tool design to these new developments.

In so far as tool design is concerned, light alloys and plastics present peculiar problems. Thus these two materials are easy to machine when compared with steels on the basis of the ease of removal of material, but the tools used on them are subject to a very abrasive action, and for this reason it is most desirable to use hard metals. They can easily be applied in the form of turning tools, but the majority of the machining operations on these materials call for more specialised tooling, particularly sawing, drilling, milling and routing. In the design of these special tools the strength of the cutting edge, which has to be so carefully considered, is weakened by the cutting angles necessary, and by the large flutes or gullets which must be provided for reception of the swarf during cutting.

Moreover, the design has had to be adjusted to give very free cutting action for with plastic materials heat generated would cause gumming of the tool which soon results in its destruction, while light alloys readily form a "built-up edge." This also calls for very highly finished tools.

The degree of success which has been achieved in this work is illustrated in the following examples.

Fig. 4 shows a photograph of a 32 in. hard metal tipped saw which was used for cutting off riser heads from a cast aluminium crank case. Two saws were

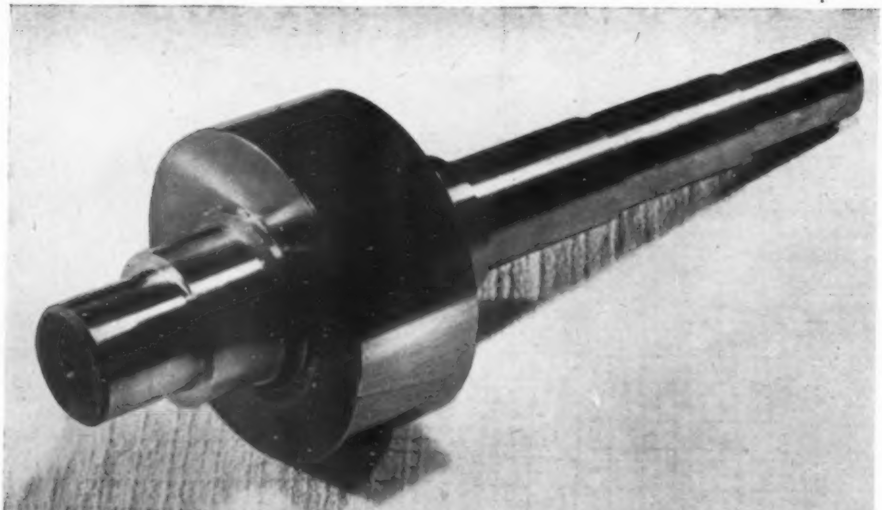


Fig. 7.—A wire-flattening roll in hard metal.

arranged to cut through castings roughly 13×44 in., at a cutting speed of 3,000 ft./min., with a feed of 36 in./min.: under these conditions the saws completed over 1,300 castings before reconditioning. This compares with 120 from high-speed steel saws previously used.

Similarly successful results are achieved with hard metal tipped saws on wood or composite boards. A typical instance is that of a 14-in. dia. tipped saw cutting 43,000 ft. of ½-in. thick plywood as compared with 500 ft. obtained from a steel saw per regrind. On "chip boards," composed of wood chips and phenolic resin, hard metal tipped saws will cut 2,800 ft., as against 100 ft. per a steel saw per regrind. In this latter instance the, cutting speed was also increased by the use of the tipped saw from 100 to 150 ft. per min. Again emphasising the necessity for careful design is the use of hard metal in rock drilling. The use of the tougher grades, coupled with careful design of body, has enabled hard metal to be used for percussive drills for use in drilling all types of rock including the hardest granite. The use of such drills can show substantial economies over the use of the normal tool steel drill.

Forming Tools

Hard metal tools have been used for many years for metal forming, and no doubt many readers are familiar with the performance of hard metal dies for wire, bar and tube drawing. This, as mentioned above, was one of the first uses to which they were put and comprises one of the most important fields of application. During the war, however, the tougher grades of hard metal were applied successfully to intermittent drawing and forming operations, often withstanding shock loads to a surprising degree. Inserts in press tools have been used for the drawing of small cartridge cases with most successful results, dies producing 500,000 pieces as against 10,000 for similar steel dies while a still more recent application has been the use of hard metal for the cold heading of bolts and rivets. The tools include cut-off knives and quills for cutting wire or rod to length, and hammers and dies in which the rivet head is formed. Fig. 5 shows a hard metal hammer and heading die which is used for making $\frac{3}{16}$-in. dia. rivets from aluminium alloy and steel wire. To those not familiar with this type of work it will be of interest to know that each rivet head is cold forged with a single blow of the hammer at the rate of up to 200 per min. This gives some idea of the shock the tools have to withstand. The best performance obtained with these dies runs about 11 million rivets, compared with 12,000–15,000 from the best steel dies, while an average performance is 4 or 5 million working on aluminium alloys. Working on mild steel between 2–5 million rivets are produced before failure. As in the case of other types of hard metal tools, considerable care is necessary to obtain these results, and only the best machines are found to be really suitable.

A similar job is the use of dies for the formation of steel balls for ball-bearing manufacture which are cold forged to shape from sheared lengths of steel wire or rod. The life of such dies which have to stand very severe shock loads is roughly 10 times that of similar steel dies. The grades of hard metal used for this type of work are the toughest of the tungsten carbide/cobalt type and contain upwards of 20% of cobalt. It is interesting to note that although the life of these grades is many times

Fig. 8.—Wear resisting parts.

that of steel, the hardness is no greater than that of the tool steels used for the same work.

Other successfully applied tools, such as the swaging dies shown in Fig. 6, amply illustrate the fact that by employing the correct grade hard metal may be used for applications where a few years ago they would have been dismissed out of hand as being too brittle.

Among new applications which come under the heading of forming tools which, while they have not to resist great shock are nevertheless subject to very severe stresses, are rolls for the cold rolling of strip and wire. So far the development of these products has reached its highest level in the case of wire flattening rolls (one of which is illustrated in Fig. 7), but there is every indication that with further work, particularly on the production of the large pieces of hard metal involved, success will result in many cases of the cold-rolling of metals.

Wear-resisting Parts

Although some few applications have been known for a long time, the use of hard metal in the form of inserts whose sole duty is to resist wear is the most recent field of development in the industry. The results of using hard metal for this purpose are so beneficial that it is surprising that earlier development on a large scale had not taken place. This has probably been due to lack of knowledge on the part of engineers of the properties of hard metal, for which in the early days of hard metal development the manufacturers were probably to blame.

One of the earliest applications to wear-resisting parts was the use of hard metal inserts in guides in textile machinery to combat the abrasive action of cotton or similar threads. Such inserts were successful in having a life of several hundred times that of the best competitive material. Many thousands of such inserts have been used, and now they are not only used on textile machinery but also on machinery used for weaving wire, for instance in the manufacture of steel wool for pan cleaners, for guiding wrapping material of all types in the insulating of wire, and as inserts in sewing machines used in the manufacture of footwear.

Hard metal has also been used in bearings with very successful results, the hard metal being used in contact with hard metal or with graphite. Such bearings are used in certain special types of pump.

Hard metal is also used very successfully in certain small high-speed spindles, the bearings consisting of two mating parts of different grades. Such bearings will run, if necessary, without lubricant, and although overheating may in such cases occur, the bearing parts appear to remain undamaged. Fig. 8 shows a group of wear-resisting parts which include a bearing ring for a thrust bearing.

Hard metal for wear-resisting parts is usually used in the form of inserts at the point where wear occurs. These may be attached to the main body of the machine or apparatus by mechanical means, by brazing, or by soft soldering, for the latter process can provide a very sound attachment if the temperatures of operation are not high.

It should be emphasised that hard metal for wear-resisting parts has been an economic success, in spite of the relatively high cost of the hard metal parts as against competitive material. There is every indication that in future the use of hard metals for wear-resisting parts will grow rapidly and will depend upon the ability of the hard metal manufacturer to produce the complicated shapes and the larger sized pieces often necessary for this work. It will also depend upon the degree to which this type of application becomes known to industry.

Acknowledgment

The author expresses his indebtedness to Dr. Sykes, F.R.S., Director of the Brown-Firth Research Laboratories, Sheffield, for permission to present this paper.

German Division, Board of Trade Services to Industry

The German Division of the Board of Trade maintains an organisation called Technical Information and Documents Unit at 40, Cadogan Square, for the purpose of disseminating the results of technical investigations undertaken in Germany and also giving technical advice on war-time industrial processes in that country. The published CIOS, BIOS and FIAT Reports are already well known through their sale by H.M. Stationery Office and the free distribution to libraries and scientific institutions throughout the country. It is not, however, so widely appreciated that in addition to, and in support of, these reports, T.I.D.U. maintains a large library of original German documents, treatise and research reports. These documents (as distinct from reports) are available for consultation at T.I.D.U. and, moreover, facilities are provided for having copies made in microfilm, microfilm print or photostat form at the cost of reproduction. Notification of the accession of individual documents to the library is made by the issue of F.D. summaries written in English on yellow foolscap paper. These summaries are sent to trade and research associations and to a limited number of firms.

Another aspect of the work of T.I.D.U. which is sometimes overlooked arises from the very close co-operation of the unit with its American counterpart, the Office of Technical Services, Department of Commerce, Washington. As a result of this co-operation T.I.D.U. has most of the material concerning enemy countries announced in the American Bibliography of Scientific and Industrial Reports under P.B. numbers. It is, therefore, advisable to check with T.I.D.U. before ordering from America any document or report bearing a P.B. reference Number.

At present a series of reports known as BIOS Overall Reports is being published. These reports are surveys of the individual industries and attempt to answer the question : " What has Britain to learn from Germany ? " This could not be answered until all the available information had been brought over to this country and until British experts had carefully gone through the material and compared it critically with the latest British practice in their own field, because it was felt to be of the utmost importance that this question should be answered as quickly and as fully as possible, The Board of Trade, which is now responsible for B.I.O.S. approached experts in each of the major fields and asked them to reply in the form of critical summaries suitable for publication.

Requests for review copies should be addressed directly to : Board of Trade, T.I.D.U., Research Section, 40, Cadogan Square, London, S.W.1. Telephone : KENsington 5131, Ext. 149.

Electro-Zinc Phosphate Coatings for Iron and Steel

By E. E. Halls

Some test results are given which have been obtained by the direct electro-zinc phosphatisation of iron and steel. These results indicate that the combined process has much to commend it. In some cases it gives a better finish than is provided by phosphatisation alone, and in others a better finish than that by phosphatising over electro-zinc coatings.

THE desirability of passivating electro-zinc coatings for a number of purposes—namely, firstly to minimise the tendency to white corrosion and, secondly, for improving the adhesion of applied organic coatings such as enamel, raises the question of combining this treatment with the electro-deposition process. There are available, at least two established methods of achieving this.

The results obtained by the direct electro-zinc phosphatisation of iron and steel are not the same as those obtained by phosphatising electro-zinc deposits. The one procedure, therefore, cannot replace the other in all its uses, but there are many instances where this can be done and some in which it is distinctly advantageous.

The following presents test results in illustration of this point.

Perhaps the best established process of electro-zinc phosphatisation uses A.C. current applied to work thoroughly cleaned in one of the orthodox series of cleaning operations. The solution used is employed at 140°–165° F. and the current density consumed is of the order of 36 amps./sq. ft., with a voltage of 6–15 v. The average time of treatment is only 3 mins.

Small parts can be barrel treated by a procedure similar to that employed in barrel electro-plating. The voltage required is about 25 v. The vats can be of mild steel or they may be wood, or rubber, lined. The use of alternating current is an economic advantage, but it

TABLE I.—MILD STEEL PRESSED COMPONENTS, WITH VARIOUS PRETREATMENTS, ENAMELLED, SUBJECTED TO SALT-SPRAY TESTS

Sample No.	1	2	3	4
Preparatory Treatment	Trichlorethylene Degreased only.	Trichlorethylene Degreased only.	Trichlorethylene Degreased and immersion phosphatised for 3 mins.	Trichlorethylene Degreased and electro-phosphatised.
Enamel Finish	Two coats grey synthetic stoving enamel.	Stoved synthetic zinc chromate primer and one coat stoved finishing enamel.	Two coats grey synthetic stoving enamel.	Two coats grey synthetic enamel, stoved.
Period of Test: 4 days	Rusting at edges.	Unchanged.	Unchanged.	Unchanged.
14 days	Rusting at edges heavy.	Rusting at edges fairly heavy.	Slight rusting along edges.	Slight rusting at edges.
28 days	Rusting spreading inwards for edges, blistering the enamel; adhesion of enamel poor.	No very marked change.	Slight increase in rusting at edges.	No change.
42 days	—	Some blistering of enamel near edges, making adhesion poor, although unchanged on main surfaces.	ditto	No change.
56 days	—	Finish deteriorated a little further.	Rusting at edges fairly heavy.	No change.
84 days	—	Rusting spread inwards from edges appreciably, much blistering of enamel and adhesion rather poor.	Little further change.	No change.
98 days	—	—	Slight blistering of enamel from edges, but general condition still good, and adhesion except at the blisters (confined near edges) still excellent.	No change.
365 days	—	—	—	Very little deterioration, no blisters apparent, and adhesion still excellent.

TABLE II.—DRAWN STEEL SECTION, WITH VARIOUS PRE-TREATMENTS, ENAMELLED, SUBJECTED TO SALT-SPRAY TESTS

Sample No.	1	2	3
Preparatory Treatment	Degreased by trichlorethylene only.	Degreased by trichlorethylene and immersion phosphatised for 3 mins.	Trichlorethylene degreased and electrophosphatised.
Enamel Finish	Two coats of stoved grey synthetic finishing enamel.	Two coats of stoved grey synthetic finishing enamel.	Two coats of stoved grey synthetic finishing enamel.
Period of Test: 7 days	Rusting at edges.	No significant effect.	Unaffected.
14 days	Marked spreading of rust from edges.	Rusting at edges.	Unaffected.
28 days	Enamel blistering from edges and adhesion generally very poor.	No marked change.	Unaffected.
84 days	—	Rusting still confined to edges, where a little blistering was also observed.	Unaffected.
126 days	—	No marked change, adhesion still very good.	Traces only of rust at edges, otherwise no deterioration and condition excellent.

TABLE III.—SUPERIORITY OF STOVED FINISHES COMPARED WITH CELLULOSE FINISHES ON ELECTRO-PHOSPHATISED STEEL SHOWN BY DURABILITY UNDER HUMIDITY TESTS

Sample No.	Enamel Finish	Behaviour under Humidity Test
1	Two coats grey cellulose enamel on electro-phosphatised steel panels.	Enamel embrittled, and scratch and bend tests showed adhesion very poor in 40 days.
2	Two coats stoved grey synthetic (alkyd-urea type) enamel on electrophosphatised steel panels.	Finish satisfactory, and adhesion unimpaired in 360 days.
3	Cellulose finish as in (1) on electro-phosphatised steel tubular components.	Enamel failed in about 40 days, as for Sample 1.
4	Stoved finish as in (2) on electro-phosphatised steel tubular components.	Enamel unimpaired in 360 days as for Sample 2.

also assists in ensuring very uniform throwing power so that the treated surfaces are processed over their entire areas exceedingly uniformly. The very rapid time of processing will be noted, which is far shorter than that associated with zinc electro-deposition methods.

The result of the treatment is a dark grey coating, consisting mainly of a zinc phosphate in intimate bond with the base material. This coating gives a very good key for the adhesion of organic coatings of oil, lacquer, or enamel and in itself has some rust resisting properties. Its peculiarities can be assessed, at least to some extent, by examination of the tabulated data covering the exposure tests under various conditions.

The tests include the following :—

1. *Salt spray.*—This comprises exposure to the mist from 20% salt solution atomised with compressed air. The samples were exposed to the mist for 8 hours and left in the mist-laden chamber for the remainder of the 24-hour day, being removed at the end of the period for washing in cold water and drying on a soft cloth.
2. *Fluctuating humidity test.*—In this, specimens were exposed to an atmosphere of 55°–60° C., with 65–75% humidity during the 8-hour day and allowed to cool off to atmospheric temperature during the night, with humidity rising to 100% and moisture condensing on the work.
3. *Open atmospheric conditions.*—This merely comprises exposing specimens freely to open weather conditions, facing south-west, in a semi-industrial atmosphere, without any protection from direct rain, etc.

Table I gives the salt-spray results on enamelled mild steel pressings, having various pre-treatments. The information is self-explanatory and it will be seen that with improving pre-treatment, the specimens show progressing superiority. Thus, Sample No. 1, without any preparation other than degreasing, is poor. Sample No. 2, having a very special primer, is markedly better. Sample No. 3, with immersion phosphatising direct on steel, is very good, while No. 4, with the electro-phosphatising, is outstandingly the best.

Table II gives similar results for drawn steel section and similar conclusions are drawn from a detailed examination of these. It will be noted that for the tests covered in Tables I and II, the enamel finish has been a stoved one, and in Table III the performance of cellulose enamel is compared with stoved enamel. It will be seen that the cellulose is markedly inferior. Consequently, it is considered that specific consideration has to be given to the suitability of the electro-zinc phosphatised process in relation to the type of finishing media that are to be employed.

Steel springs are always very difficult to finish satisfactorily, hard organic coatings flake off, soft organic coatings of oil and jelly are not entirely satisfactory and electro-plating coatings often cause embrittlement.

TABLE IV.—EXPOSURE TEST RESULTS ON SPRING STEEL WITH VARIOUS FINISHES

Sample No.	1	2	3
Finish	Cleaned and colourless cellulose lacquer only	Cleaned and electro-phosphatised only	Cleaned, electro-phosphatised and colourless cellulose lacquer
SALT-SPRAY TEST : Period 1 day	Heavy rusting and blackening of the steel; lacquer completely peeled off.	50% of surfaces slightly rusted.	Unaffected.
2 days	—	General rusting fairly heavy.	Ditto.
3 days	—	—	Slight rusting along edges.
14 days	—	—	Edges completely rusted, lacquer blistering, and a little rust on main surfaces.
HUMIDITY TEST : Period 3 days	Tiny rust spots generally developing.	Very slight rusting general.	Slight rusting fairly general.
10 days	Lacquer peeling from all surfaces.	Fairly heavy rusting general.	Some rust on all surfaces and lacquer generally peeling.
ATMOSPHERIC TEST : Period 14 days	Isolated but heavy rust spots on general surfaces, and lacquer peeling at edges.	Slight general rusting evident.	No rusting apparent : lacquer showing tendency to peel generally.
21 days	Rusting heavy, lacquer peeled off, and condition very poor.	Rusting still only slight and superficial.	Rusting only very slight and superficial, but lacquer mainly peeled off.

TABLE V.—ELECTRO-PHOSPHATISED IRON AND STEEL COMPONENTS, WITHOUT ADDITIONAL FINISH, SUBJECTED TO DURABILITY TESTS

Sample No.	Type of Electro-phosphatised Samples	Nature of Test Conditions		
		Salt Spray	Humidity	Open Atmospheric
1	Small B.A. threaded screws.	All rusted in 1 day, heavily in 2 days.	Slight rusting in 2 days and fairly heavy rusting in 8 days.	Some slight rusting generally developed in a few days, with little further deterioration in 30 days. Condition quite good.
2	Iron castings.	Ditto.	Slight rusting in 1 day, and fairly heavy rusting in 6 days.	Ditto.
3	Steel pressings.	Ditto.	Slight rusting in 1 day, gradually developing to fairly heavy rusting in 10 days.	Ditto.

TABLE VI.—LABORATORY CHARACTERISTICS OF ORGANIC MEDIA EMPLOYED ON TEST SAMPLES

Medium	Compositional %		Physical		Other data
	Volatile Spirit	Total Solids	Viscosity at 25° C., centipoises	Specific Gravity at 25° C.	
Grey pigmented synthetic stoving enamel	55·8	44·2	405	1·100	Stoved 30 mins. at 250° F.
Stoving zinc chromate primer, synthetic alkyd-urea type	56·5	43·5	175	1·125	Ditto
Colourless cellulose lacquer	80·6	19·4	1350	0·950	Diluted 3 parts with 1 part of thinner for spraying.
Grey pigmented cellulose enamel ..	56·8	43·2	1100	1·115	Diluted 2 parts with 1 part of thinner for spraying.

Results of a study are briefly summarised in Table IV. From this it may be seen that with the springs electro-phosphatised without additional finish (Samples No. 2), considerable protection against rust is achieved. Such a finish, in conjunction with oil or jelly, can, therefore, be really good. Samples Nos. 3 cover the same finish with clear lacquer additionally, and it will be seen that the additional adhesion given to the lacquer by the electro-phosphatisation makes this finish a very good one. It markedly contrasts with Samples No. 1 on which the finish comprised cleaning and lacquering only.

Finally, in Table V, electro-phosphatised components having no additional finish are subjected to the various tests in order to determine how quickly they deteriorate. It will be seen that under the very severe salt-spray conditions they all fail quickly. Under the relatively mild humidity conditions they all fail fairly quickly. Under open weather conditions their performance is quite good. These results do indicate that the finish should not be used without additional protection by means of an organic coating.

The various organic media involved in the tests are characterised in Table VI.

It is evident that the combined process of electro-zinc phosphatisation has much to recommend it. For work that is to be enamelled it represents a better finish than provided by phosphatisation alone, and in some cases a better finish than that given by phosphatising over electro-zinc coatings. The speed of the process and the ease with which it can be performed should make it more generally adopted. For specific purposes such as small screws, springs and components of that nature, it has advantages. It does not cause any interference with dimensional fits; for example, in the case of small BA screws of size 6–8 BA treated by the barrel process, it was found that the influence on dimensions was as follows:—

Overall Diameter	..	A Decrease of 0·00075 in.
Effective ,,	..	An Increase of 0·0011 in.
Root ,,	..	An Increase of 0·00057 in.

These changes are on the diameter and they are not sufficient to cause any difficulties. This, therefore, is another merit of this method of finishing.

Imperial Institute's Annual Report

Inter-Commonwealth Developments

Every year the report of the Imperial Institute, South Kensington, heralds the coming of new industries and new crops to many parts of the British Commonwealth. The one recently issued for 1947 shows that an unusually large number of economic inquiries and laboratory tests—pointers to fresh developments—have been made at the Institute for Empire Governments, industrial research organisations and commercial firms in search of new sources of raw materials.

The stress of present economic conditions and the consequent reaction against hard currencies have tended greatly to encourage the development of mineral and agricultural products within the Commonwealth; a tendency which is well reflected in the report. Much use has been made of the information services of the Institute in the conduct of the extensive surveys of the resources of the Colonial territories that are now in hand, particularly in regard to coal in Nigeria, Sarawak, Brunei and North Borneo. It is gratifying to note that the increase in demand for high-grade refractories has led at last to the development of the extensive deposits of kyanite in Kenya and the shipment of large quantities of this mineral to the United States.

Many inquirers about vermiculite have been told of supplies in South Africa, Kenya, Uganda, Tanganyika and Australia, and American demand for the mineral has increased interest in some of the less well-known Empire sources. Requests from hard currency countries for pyrophillite has drawn attention to Indian and Australian supplies.

A prominent British oil company has been in search of large Empire supplies of barytes for weighting oil-well drilling muds in order to replace those from hard currency areas. Its requirements were circulated to Empire geological surveys and mining departments, and favourable replies from Australia, South Africa, India, Swaziland, Tanganyika, Kenya and Eire are being considered.

With regard to far Eastern countries, we are told that samples of a newly discovered manganese ore in Burma contained 83·95% of manganese dioxide, and that it is a promising material of chemical grade. The Burma Government, moreover, was supplied with preliminary advice as to the possible exploitation of certain zinc carbonate deposits and their use in making zinc oxide. A supposed "slag" left behind in Malaya by the Japanese proved on test to be elemental silicon worth about £97 a ton.

Work done for official geological surveys, mines departments and other branches of the Colonial Service has been of paramount importance. To meet heavier calls on its resources, the Institute's laboratories will soon be better equipped to deal with the more complex analytical and investigatory problems with which they are frequently confronted. A new spectrographic laboratory, which will house one of the most modern instruments, has been installed. A new laboratory for X-ray examination of minerals has also been provisionally approved and other modern apparatus is being added to the existing chemical and mineralogical laboratories.

Detergents, Wetting and Emulsifying Agents

Their Use in Metal Cleaning

THE London Section of the Society of Chemical Industry held a symposium on April 5th and 6th on "Detergents, Wetting and Emulsifying Agents." The success of this new venture of holding a two-day meeting devoted to one group of topics may well be judged from the fact that over two hundred members were present. The programme was divided into afternoon and evening sessions, thus enabling a maximum number of people to attend.

In view of the wide use of these materials in the textile industry many papers which were read were biased in this direction, but the use of detergents for the cleaning of metals was discussed by P. D. Liddiard of The Glacier Metal Co. Ltd.

In his opening remarks Mr. Liddiard pointed out that the need for a cleaning stage in the manufacture of any metal article was largely determined by the treatment which it was to receive after fabrication and as examples of such treatments, tinning, enamelling, painting and galvanising were quoted. The process of degreasing may be subdivided into chemical, physical and mechanical methods as illustrated by saponification, emulsification and pressure washing, respectively. The process of degreasing cannot readily be differentiated from pickling except that the former is performed in alkaline solution while an acid solution is used for the latter.

There are many ways by which grease may be removed and the best method can only be chosen after a consideration of the many factors involved. Among the more important of these factors may be mentioned the previous history of the metal, whether it has been drawn, quenched in oil, or had a lanoline protection; the nature of the deposit which may be water soluble or insoluble and the treatment which the metal is to receive after cleaning.

In considering a simple example, such as a material with an oil base absorbed on a metal surface, it was pointed out that the rate of wetting influences the rate of cleaning and is often the longest time factor involved. The next stage in the cleaning process is assumed to be the emulsification of the oil and it is essential that this stage should be complete in order to prevent a scum of oil forming on top of the cleaning bath.

Although alkalies have been the basis of most detergents for many years, their efficiency is not very good and the use of caustic soda alone is very slow unless there is good mechanical agitation. The more modern practice is to use a caustic alkali in conjunction with phosphates and silicates, which latter combine the advantages of soaps and alkalies, while the addition of highly surface active materials is finding increasing favour. All these improvements are actuated by the desire to obtain rapid wetting of the deposit and the metal surface, with the subsequent deflocculation of the more solid media and emulsification of oily residues.

The speaker next mentioned the removal of oil and dirt by gassing. In this type of process the metal to be cleaned is made the anode or the cathode of an electrolytic cell and a current density of 50/80 amps./sq. ft. is used. This method is of great use for the removal of polishing wax residues. The volume of hydrogen coming off at the cathode is, of course, only half that of the oxygen at the anode but some metals are sensitive to oxidation and must, therefore, not be made the anode of a cell. With regard to the solution used in a gassing process there are two main requirements. Firstly, that the solution shall have a high conductivity, and secondly, that there shall not be anything in the solution which can plate out on the metal being cleaned.

When the article has been degreased it must next be rinsed and trouble is likely to be encountered here if hard water has to be used for this stage. It has been found that the addition of 0·001% hexametaphosphate ("Calgon") to the rinse liquor is a great advantage in the removal of the last traces of caustic soda whether the water be hard or soft. It is possible that an article may wet completely even if it is not completely clean and this may give trouble in a subsequent stage, e.g., pickling. This is caused by the dirt on the metal having absorbed some of the degreasing agent and for this reason it is best to agitate the rinsing bath.

Metal surfaces are attacked in various ways: the attack may be direct as in the case of aluminium, tin, zinc and lead, but usually it is a complex corrosion process. This may be minimised by preventing contact between different metals in ionic baths or by the use of some special type of bath as instanced by the addition of sodium sulphite to a tin bath to prevent feathering.

When an organic solvent such as trichlorethylene is used for the removal of grease, it is often advantageous to follow this with an aqueous alkali bath especially if the metal is subsequently to be used in an aqueous process such as electroplating.

From the point of view of the industrialist, cleaning is apt to be looked on as the Cinderella of the various manufacturing operations and for that reason much thought has been given to speeding up this stage in production. One way of doing this is by using pressure washers but since such machines are normally "tailor made" to suit one individual process they tend to be rather expensive. One such machine for cleaning steel strip is 150 ft. long and a jet of detergent impinges on the strip for one second after which it passes between electrodes for 6 secs. (low voltage, high current), is brushed and rinsed for 1 sec. By this means the strip is cleaned at the rate of 15 ft./sec.

In conclusion, Mr. Liddiard mentioned that the satisfactory cleaning of aluminium and its alloys still presents a major problem.

The British Aluminium Co., Ltd., Midland Warehouse

The Midland Warehouse at 17/18, Providence Street, Cradley Heath, Staffs., is now in full operation. The telephone number is Cradley Heath 6881. The Company's Midland Branch Office remains at Lansdowne House, 41, Water Street, Birmingham, 3. (Telephone No.: Central 3053; Telegrams: Britalumin, Birmingham).

Tests on New Paint Inhibitors

Interim Results of Work in Progress

EXTENSIVE recent developments in the ranges of media and inhibitive pigments available for the preparation of priming paints have considerably influenced anti-corrosion researches on iron and steel.

Some interim details of work in this connection by the Protective Coatings Sub-Committee of the Iron and Steel Institute and the British Iron and Steel Research Association have recently been made known.[1] This work is a natural sequel to the Sub-Committee's previous investigations on the paramount importance of careful preparation of steel surfaces prior to paint application.

A panel has accordingly been set up by the joint Sub-Committee in collaboration with the National Federation of Associated Paint, Colour and Varnish Manufacturers of the United Kingdom, the Society of British Paint Manufacturers, Ltd., and the Association of Manufacturers of Bituminous Protective Products, Ltd. This joint technical panel is testing 100 formulated priming paints, suitable for brush application, by exposure on steel plates. A standard finishing coat was applied, and the exposure tests have duplicated in an industrial atmosphere (Derby) and a marine atmosphere (Brixham).

Twelve experimental binding media are under test; these are a linseed stand oil/alkali-refined linseed oil; five alkyd media of various compositions; one 100% phenolic and two modified phenolic media; two coumarone media and a natural resin medium.

Twelve different pigments are under investigation—namely, asbestine, barium chromate, basic lead chromate, basic lead sulphate, Burntisland red, chromated white lead, ferrous ammonium phosphate, red lead, white lead, zinc chromate, zinc oxide and zinc tetrahydroxychromate. Various binary or ternary mixtures of these have been incorporated in the media prepared for test. Asbestine is not used as a major pigment but as a standard extender throughout and forms 20% of the total pigment content in the case of the ternary mixtures.

Care was taken to ensure that all the paints were prepared under conditions approximating as closely as possible to large-scale production and that they were applied to steel specimens in typical and standardised states of surface preparation. In order to give the maximum practical bias to the results, considerable importance was attached to conducting tests on weathered and wire-brushed steel carrying millscale.

The tests will not reach their first stage of completion until later this year, but after six months certain interim observations were made.

These interim results indicate that, when considering the effect of this formulation of a priming paint on the protective value of a painting scheme, due regard must be paid to the factor of paint film thickness—i.e., the behaviour of any given painting scheme must be considered in relation to the average performance of other schemes of the same thickness. Even with skilled application of the paint under good conditions, the specimens concerned showed a variation in paint film thickness between 50 and 120 microns, though 50% of the specimens fell between 60 and 80 microns and over 40% between 80 and 100 microns. Assessments of the deterioration of the specimens based on blistering, flaking and rusting show that there is a distinct correlation between the average performance of a group of painting schemes and their average paint film thickness.

Another variable is introduced by the difficulty of reproducing standardised degrees of descaling on the surface of a large number of steel specimens prepared for painting by weathering and wire-brushing. As a result of experience in this test series, the Panel has made certain alterations in the experimental procedure which should reduce these variations and also the variations in paint film thickness mentioned above.

Another interesting interim observation concerns the comparative rates of deterioration of the paints at Brixham and Derby. Although the average paint film thickness at Brixham (52 microns) is slightly greater than that at Derby (47 microns) it appears that up to six months the rate of deterioration is more rapid in the marine than in the industrial atmosphere. This observation is confirmed when the merit figure in each case is correlated with paint film thickness.

[1] "Interim Report on the First Series of Tests on Formulated Priming Paints for Structural Steelwork (RJ28)," by Joint Technical Panel J/P1—Paints for Structural Steelwork. December, 1946. Copies are available from the British Iron and Steel Research Association.

The Measurement of Secondary Current, Voltage and Electrode Load Cycles for Spot-welding Machines

A REPORT on the above subject by Dr. G. E. Bennett and Mr. H. E. Dixon is published in the April issue of *Welding Research*, the official supplement to the Transactions of the Institute of Welding. The report deals with methods of measuring simultaneously the secondary current, the secondary voltage and the tip load of a capacity storage type spot welder of a size suitable for spot welding up to 2 × 10 S.W.G. light alloy. The physical and metallurgical characteristics of the spot weld depend on the correct relationship between current and tip load, on the magnitude of both, and on the rate of change of load with time, and it is impossible to produce welds of a consistent and satisfactory nature without proper control of these variables. Equipment for measuring these and the method of using it are described in this Report.

For current measurements, the authors used an air-cored toroidal coil surrounding the electrode of the spot welder. The toroidal coil produces a voltage proportional to the rate of change of current and an integrating following circuit is required to give a voltage output proportional to the welding current. The Report gives details of toroid design of the limits of accuracy and of the method of calibration.

For measuring tip load a special member was introduced and the strain of the member was converted to a change of capacitance, and also of resistance in the circuit. A full description is given of the pick-up units and the different circuits and equipment that can be used to convert the tip force into an oscillgraph deflexion directly proportional to the load and free of spurious results and interference that can arise from the welder current and other causes. The Report describes a three element cathode ray oscilloscope for simultaneous recording, employing a drum-type camera with a paper speed of 7·5 in. per sec. Alternative equipment that could be used is mentioned.

Salts for Heat-Treatment

By Ernest Hague

(*Electric Resistance Furnace Co., Ltd.*)

The use of liquid baths for heat-treatment of metals and alloys has many advantages especially in the uniformity of heating throughout the mass of the component treated and the maximum elimination of hardening strains obtainable at the temperature used. The subject is discussed on general lines, the author being primarily concerned with practical issues.

MOLTEN salts are now widely used for routine heat-treatments such as: hardening and annealing of carbon and stainless steels, heating for forging, liquid carburising, cyaniding, high-speed steel hardening, tempering and for numerous special processes, including descaling, de-enamelling, brazing, heat-treatment of aluminium alloys, liquid nitriding and isothermal treatment.

The main advantages of the salt-bath method of heat-treating are :—

1. *Rapid and uniform heating.*—Conduction heating in salt baths is more rapid and uniform than radiation heating, yet no thermal shock is encountered ; the molten salt freezes on cold metal at the moment of immersion, insulating it until the metal has exceeded in temperature the melting point of the salt. As an example of the rate of heating, a 1-in. square bar can be heated in a salt bath to 800° C. in 6 mins., whereas in a muffle furnace the time would be approximately 30 mins.
2. *Freedom from scale.*—Molten salt protects metal surfaces by excluding air during immersion ; after removal of the metal from the bath, the salt is present as a thin film until the metal is quenched, or while it is cooled in air.
3. *Accurate temperature control.*—Parts treated in molten salts attain the same temperature as the bath. There are no hot or cold spots in molten salts.
4. *Reduction of distortion.*—Uniform heating, freedom from scale and accurate temperature control effectively reduce distortion of metal parts. Moreover, long slender components, such as broaches may conveniently be suspended.
5. *Selectivity.*—Parts may be partially immersed in salt baths for selective heating or carburising.
6. *Moderate costs.*—Because of the rapid rate of heating, a minimum size of plant is necessary and, in addition, highly trained operators are not essential.

The following elementary precautions should be taken when using salt baths :—

(*a*) The parts to be treated must be perfectly dry before immersing in the salt in order to eliminate the possibility of popping and spitting which results from water meeting a molten salt.

(*b*) To reduce the explosion hazard when using nitrate salts, care must be taken to ensure that no carbonaceous material finds its way into the salt, and when such a bath is used for aluminium alloys, it is important to prevent local overheating and the build up of sludge, etc.

It is known that a combination of an over-run of temperature with an accumulation of sludge and aluminium parts, lying in the bottom of the tank can bring about an endothermic reaction which may reach explosive force. Such explosions have occurred and investigations have shown that the cause is invariably due to neglect of the elementary precaution of keeping the bath clean.

Post treatment rusting, at one time a disadvantage, is now avoided by thorough washing of the parts. Dipping in de-watering fluid followed by a dip in anti-corrosive oil will prevent any corrosion so that parts treated in salt baths have now a much better finish on leaving the shop.

Hardening and Annealing

For straight hardening, annealing, etc., "Neutral" salts are used, so termed because they are neither carburising or decarburising in action. They are available with varying temperature ranges, enabling any working temperature between 150° and 1,350° C. to be obtained.

Unfortunately, there is no one salt capable of serving the full range so, where working ranges overlap, the choice of salt is largely a matter of individual preference. The following factors should, however, be taken into consideration.

(*a*) The operating temperature should coincide as nearly as possible with the centre of the working range. For instance, a salt with a working range of 705°–900° C. is often used for hardening at 780°–820° C.

(*b*) If other operating temperatures are likely to be required in the future, a salt which will, if possible, cover the widest range required, should be provided at the outset.

(*c*) The salt should be, where possible, fluid, non-corrosive, easy to clean and non-hygroscopic, features, incidentally, possessed by the salt referred to under (*a*).

(*d*) The obvious factor of initial cost.

The salts may be obtained in either crystalline or anhydrous form, the latter being preferred because of its freedom from moisture. This feature ensures that there is no attack of the work, the pot, if of metal, fume ducts, etc., and in addition, as there is no moisture to evaporate, the cost of melting the salt is at a minimum.

Liquid Carburising

The liquid carburising process is used to produce uniform carbon case depths ranging from a few thousandths to an eighth of an inch. The rate of penetration for any given cyanide content varies with the operating temperature and the time it is maintained at this temperature. For a given temperature and time, the penetration increases for cyanide content up to a certain maximum.

Fig. 1.—A typical salt-bath installation for the heat-treatment of high-speed steel.

For instance, a case depth of 30 thou. can be obtained in just over 4 hours with a temperature of 845° C., but with a temperature of 955° C. the same depth of case can be attained in approximately 1 hour. These times are little faster than can be achieved with the more conventional pack carburising method, but the initial heating up period is very much reduced and, of course, there are no carburising boxes or carburising compounds to heat. Parts treated in carburising salts are assured of uniform case depths, a feature which does not always apply in the case of pack carburising, especially when the charge is densely packed, causing the temperature in the centre to lag behind the furnace temperature.

Moreover, liquid carburising is particularly suitable for selective carburising and for producing light cases. In some instances, involving case depths up to 10 thou., it is possible to adopt the single treatment method where the charge is quenched directly from the salt and both the refining and hardening treatments eliminated.

For case depths in excess of 30–40 thou. experience shows that most users prefer to pack carburise. This is chiefly on account of lower initial and running costs and greater convenience.

The temperature range of carburising salts is more or less standard—approximately 620°–955° C., but they are made in two or three grades in order to produce the maximum efficiency for each application. For instance, one mixture is recommended for deep cases and long heating cycles, where salt drag-out is low, another is designed for applications involving shorter cycles and higher amounts of drag-outs, and yet another for carburising parts whose design makes cleaning difficult after an oil quench. This last mixture operates at maximum efficiency where drag-out necessitates frequent replenishment.

Cyaniding

Cyanide mixtures are produced with varying cyanide contents for such purposes as reheating carburised parts, hardening finished machined parts and very light case hardening.

High-speed Steel Hardening

This is an ideal application for the salt bath. The work is treated accurately, without scale, decarburisation is avoided and distortion reduced to absolute minimum, enabling elaborate and expensive formed tools to be treated without difficulty. The preferred treatment consists of preheating to a temperature of 800°–860° C. followed by an immersion in a high heat bath maintained at 1,250°–1,320° C. The work is then transferred to a quench bath held at 560°–580° C. where it remains until its temperature has fallen to that of the salt, after which it is removed and allowed to cool in the air.

Finally the charge is secondary hardened at a temperature of 560°–580° C. in either a salt bath or a forced air furnace. A typical high-speed steel installation is shown on Fig. 1.

Heating is extremely rapid in these baths as may be judged from the following figures :—A 6-in. side and face cutter ½ in. thick attains the preheat temperature in 3–4 mins. and requires 1½–2 mins. in the high heat unit. Thus it is usual to have two charges in the preheat bath to one in the high temperature unit giving continuity of operation. A 1-in. dia. bar requires approximately 5 mins. to reach 860° C. and 2½ mins. to heat from 860°–1,250° C. For a 2-in. dia. bar approximately double these periods should be allowed.

Tempering

The normal tempering salt is of the nitrate type with a temperature range of 150°–595° C., although an alternative, and cheaper mixture is available with a temperature range of 250°–595° C. Whether salt-bath tempering is to be preferred to forced air tempering is a matter of opinion, and the decision must be determined by the requirements of the treatment. For example, if varying temperatures are likely to be involved the air furnace is to be recommended on account of its greater flexibility, whereas if differential tempering is necessary a salt bath is the better choice.

Descaling

There are two fairly well-known salt-bath methods of descaling metals, the Dupont Sodium Hydride and the Efco Virgo processes. The former employs molten caustic soda held at a temperature of 370° C. and sodium and hydrogen. The latter makes use of a patented salt mixture operating at approximately 500° C. Both have features of rapid and uniform descaling, absence of hydrogen embrittlement, and there is no attack on the base metal. This is a very important point when considering such comparatively expensive materials as stainless steels, nickel chromium alloys and high-speed steels. The plants are also suitable for de-sanding stainless steel castings, etc., and for cleaning moulds used in the glass and rubber industry.

De-Enamelling

The purpose of the process is to salvage vitreous enamelled articles which have had to be rejected owing to surface blemishes. The enamel is removed by inserting the parts in a bath of molten caustic soda held at 430–500° C. for a period of 2 to 10 mins. Usually 2 mins. will suffice to strip the enamel which collects in a sludge tray at the bottom of the bath.

An electric immersion-heater type unit is used for this application.

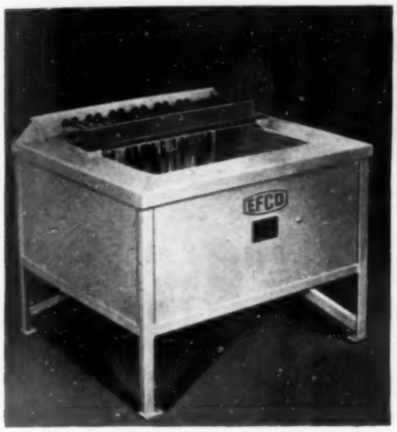


Fig. 2.—A typical salt bath of the immersion-heater type.

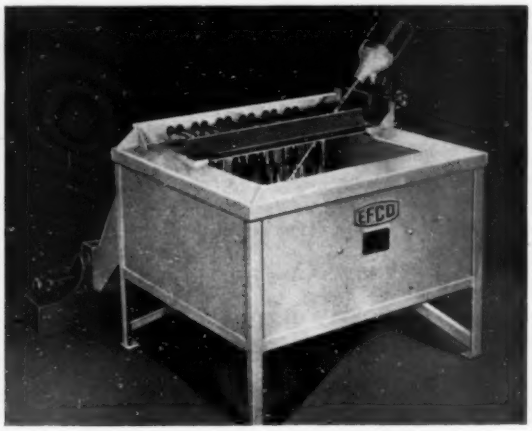


Fig. 3.— A typical salt bath for isothermal heat-treatment equipped with a fan agitator and arrangements for an airblast.

Colouring

Some salts will, at varying temperatures, produce on the work colours such as brown, several shades of blue and black. The last may be obtained between 430°–595° C., in which case certain tempering operations may be carried out at the same time. For parts that have been previously tempered, a low temperature blackening treatment is available where, after soaking in a water solution at a temperature as low as 140° C., a colour similar to the black obtained at the higher temperatures in the molten salt is produced.

Salt Bath Brazing

Although not widely used in this country there are in the U.S.A. a number of salt baths installed for such purposes as aluminium brazing, silver soldering, brass brazing and copper brazing. The first employs a special fluxing salt, the second a neutral salt, the third a cyanide mixture and the last another neutral salt, which may contain cyanide, the operating temperatures being in the order of 580°–593° C., 760°–816° C., 914° and 1,120° C., respectively.

This method of brazing is particularly suitable when the ends only of certain assemblies have to be treated. The baths can also be used when a combination of operations, such as carburising and brass brazing, brazing and hardening are required, and also, of course, for routine hardening and carburising where applicable.

Heat-treatment of Aluminium Alloys

Aluminium alloys are often heat-treated in a nitrate salt, this method being preferred by some users to the forced air circulation type furnace probably because of the extremely rapid and uniform heating obtained. A typical salt bath of the immersion-heater type is shown on Fig. 2. Baths of this type have been designed to accommodate sections up to 40 ft. long.

Liquid Nitriding

This is a means of producing a very hard case, a thou. or so thick, on the surface of high-speed tools and also for the nitriding of nitriding steels. In the case of high-speed steel tools, an increased tool life is claimed, but results have proved somewhat inconsistent, in some instances there being no improvement, but in others up to 200% increase over the normal life has been obtained.

A special salt is used which requires to be maintained at approximately 550° C., the tools being immersed for periods varying from 15 mins. upwards depending upon their size. It will be noted that the operating temperature approximates the tempering temperature of high-speed steel tools so the process has the benefit of combining casing and double tempering.

Isothermal Heat-treatment

The process involves heating the work to a normal hardening or annealing temperature followed by a

Fig. 4.—Ajax-Hultgren type electrode salt bath.

quench in a salt bath held at a specific temperature, means being provided to ensure that the temperature does not rise when the hot charge is inserted. These means usually consist of a salt fan agitator and an air blast designed to play on to the outside of the salt container. A bath thus equipped is shown on Fig. 3.

Isothermal heat-treatment may be said to apply to such subjects as martempering, austempering, cyclic annealing, and any other process requiring an interrupted quench. In the case of the first, the quench bath is maintained at 200°–260° C. and the work remains in the salt only until such time as its temperature, centre to surface has equalised whereas the other treatments require higher quench temperatures and the charge must remain in the salt at temperature not only long enough to allow the temperature outside to inside to equalise but for sufficient time to permit the required transformation of the metal structure to take effect.

Advantages of the isothermal process are that distortion is minimised and quench cracks, if not entirely eliminated, are very largely reduced and in some applications toughness and ductility are increased.

Types of Salt Baths

In the main these are either gas-fired or electrically heated. There are oil and solid fuel fired units, but these are comparatively few. The electric pattern is almost entirely of the internal heating type, being equipped with either immersion heaters for temperatures up to 550° C. or with electrodes for use up to 1,400° C. A modern electrode bath of the Efco Ajax-Hultgren type designed for use up to 1,000° C. is shown on Fig. 4.

It is equipped with electrodes consisting of straight mild steel bars 2 in. square, quick-release clamps, fume-extraction plant and a refractory or low carbon steel pot. The top opening is rectangular, a feature possible with this design of bath, and one which has proved to be of advantage on innumerable occasions. A similar type of bath is used for temperatures up to 1,400° C., but in this case it is common practice to use a circular pot of refractory material.

The outstanding feature of the Efco Ajax-Hultgren bath is the arrangement of the electrodes which produces automatic agitation of the salt itself and, in addition, allows the bath to be restarted from the solid state. Thus, there is no necessity to bale out when closing down.

The value of internal heating is appreciated when the question of pot life is considered. The salt container in an immersion-heater nitrate bath has a life of several years, and one instance can be quoted where the container is still in use after 12 years' service.

In an electrode bath operating at temperatures up to 1,000° C. the pot life varies according to the application, for example, a carburising salt requires a metal pot and the usual life is about two years. A neutral bath is fitted with a refractory lining, specially designed, and the life is four or five years. The life of the refractory lining of the high-heat unit in a high-speed steel installation is six to twelve months, and incidentally it is almost essential to use an electrode type salt bath for this purpose. An externally-heated pot would have a very short life indeed.

Gas-fired baths are, speaking generally, less expensive than electric units, although the difference in cost is less pronounced when automatic temperature control is embodied. They have the advantage of being able to melt the initial charge of salt in a quicker time, but against this must be recorded the facts that a shorter pot life is experienced and working conditions are not so good. It is impossible to give any hard and fast figures as regards pot life as this is dependent upon such factors as: Material of pot, design of furnace, working temperature, manner in which bath is used, etc.

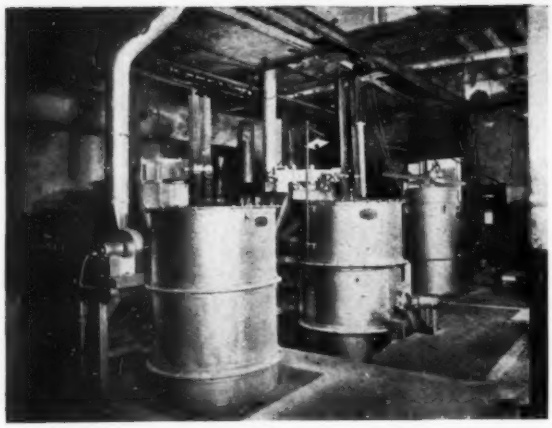


Fig. 5.—A salt-bath installation designed for hardening high-speed steel broaches.

Interesting Salt Bath Applications

A Sheffield cutlery firm has installed an Efco Ajax-Hultgren salt bath for the selective hardening of carbon steel pocket-knife blades. The bath is rated at 40 kWs. and has internal dimensions 21 in. long, 10 in. back to front, and 14 in. depth of salt. An output of good blades per hour is produced on a definite time-temperature basis which ensures that each blade is heated accurately and uniformly. There are no rejects.

Another interesting application, which will be in operation shortly, involves the hardening of stainless steel table knife blades on more or less mass-production lines, a charge of half a gross or so being immersed in the salt at a time and after heating allowed to stand in an air blast for quenching purposes. The secret of this method of working is in the design of the supporting jigs, two of which will be used in order to give continuity of operation. Preliminary tests have shown that there is no scale, no distortion, and working conditions will, of course, be excellent. This process when compared with the usual method of heating in open gas-fired furnace and removing individual blades for quenching in air-cooled clamps will, without doubt, show tremendous advantages.

Installation for Broaches

The installation shown in Fig. 5 was designed for the hardening of high-speed steel broaches up to 54 in. in length. Included is a pre-heat furnace and bath, a high heat bath and an electric forced air-tempering furnace. There is no quench bath in this instance, the parts being quenched in the tempering furnace and later secondary hardened in the same unit. A similar forced air furnace (not shown on the photograph) is used for a first preheat, and a typical time cycle is 10/15 mins. for the first pre-heat, 15 mins. for the second, 4 mins. in the high heat bath, 10 mins. in the quench furnace, and finally about 2 hours for the tempering operation.

The preheat bath is rated at 60 kWs. and the high temperature one at 120 kWs. Each contains approximately 1 ton of salt, and in order to empty the salt from the high-heat unit on occasion a traversing and tilting gear was fitted.

Annealing of stainless steel components is successfully achieved in a salt bath. Heating is extremely rapid, parts fabricated from 10 gauge material reaching the annealing temperature of 1,000°/1,050° C. within a minute. After water quenching or cooling in air, the desired softness is obtained and the original surface conditions readily restored by immersing the articles in a cold 10% nitric solution for a period of 5 mins. This time may be reduced to approx. 30 secs. by heating the solution to 65%.

Salt baths are now being used for the hardening of files, a treatment hitherto carried out almost entirely in lead pots when it is the practice to coat the files with a special compound to prevent the lead adhering to the teeth of the files. With the salt method the need for this coating is eliminated and the files are produced with a clean, silvery-grey appearance.

The foregoing gives some indication of the progress made with regard to the use of salts for heat-treatment. It is certain that the future will bring further progress resulting in many developments and applications.

Portable Cover Sheet Annealing Furnaces

By L. G. A. Leonard

The Dowson and Mason Gas Plant Co. Ltd.

The annealing of steel sheet to counteract the work hardening of the material caused by rolling is effected in a number of different types of furnaces. A recent installation for the treatment of silicon steel sheets for electrical parts is of the "Top-Hat" type and is described in this article. The annealing of silicon steel sheets is more difficult than annealing ordinary mild steel sheets, as a higher annealing temperature and a slower rate of initial cooling are necessary.

THE purpose of steel sheet annealing is to counteract the work hardening caused in rolling and thereby produce material of the required grain structure and physical characteristics for subsequent forming operations. The piles of sheets or coils are heated to a temperature below the upper critical point, the heating process being followed by a relatively slow cooling.

In the design of annealing furnaces it is necessary to consider the control of the heating and cooling cycle and the furnace atmosphere. The first enables the required physical characteristics to be obtained while the second reduces or entirely eliminates undesirable surface effects such as oxidation and discolouration. Three types are available :—

(*a*) Batch or in and out furnaces ;

(*b*) Continuous tunnel furnaces ;

(*c*) Portable lift-up cover furnaces.

This article is concerned with the development, operation and advantages of the latter type but reference will be made to the others.

Batch and Continuous Furnaces

For many years Batch and Continuous Tunnel Furnaces have been in use throughout the British Isles, but chiefly in South Wales. The sheets or coils are placed on a thick cast base and covered by a heavy inverted pot or container which is sand-sealed. In batch furnaces, the pots are usually pushed into the furnace over heavy cannon balls, races being provided in the floor of the furnace and in the underside of the base. Some furnaces have refractory bogies on which the charge is placed, but irrespective of the method of handling the covers it is necessary for the heating gases to circulate evenly.

In the older installations, the gas burner ports were arranged on one side of the charge, the gases of combustion passing over the top of the cover, down the other side to flue openings in the base. A small portion of waste gases was pulled under the charge by the action of the burners.

The possibility of impingement of the gases on the side of the annealing box led furnace designers to extend the width of the furnace chambers to allow sufficient space on the burner side. This helped to overcome the difficulty but was not always successful. Furnaces of this type are shown in Fig. 1, a line section being shown in Fig. 2.

A later improvement was the arrangement of burner ports on both sides of the annealing pots so that temperature distribution was more uniform and the rate of heating was slightly improved. The waste gases were then exhausted in the base directly under the annealing pots.

Regenerators or refractory tile recuperators are a feature of all these furnaces.

The alternate heating and cooling is a disadvantage since it will be appreciated that it is necessary to cool down the furnace to a suitable temperature before withdrawing the bogie or annealing cover.

The continuous bogie furnace was always preferable to the "in and out" furnace if the output justified the installation. In these furnaces there are three stages :—

(*a*) The heating up portion where the charged pots are heated by the waste gases ;

(*b*) The annealing portion which is the firing zone ; and

(*c*) The cooling zone or chamber.

The number of bogies in the different stages of the furnace is fixed by the required output, a common arrangement being two heating up, three annealing and two cooling down. The bogies are either pushed through the furnace with a hydraulic ram or drawn through by means of an overhead crane. The annealing cycle is controlled by the rate of charging and the temperature distribution. Means are normally provided for increasing or decreasing the length of the heated portion to provide some measure of adjustment to suit variations in practice. A section of old type continuous furnace with burners on both sides is shown in Fig. 3.

The disadvantage of this type of furnace lies in its high capital cost and the necessity of a sufficiently large output to keep the furnace in operation. While arrangements may be made to admit a protective atmosphere into the boxes or pots when discharged from the furnace and cooling on the shop floor, it is not possible to protect the charge of sheets during the passage through the furnace.

The Portable Cover Furnace

The portable lift-up cover furnace was developed to save time and labour, the original installations making use of radiant tube burners arranged vertically or horizontally. They have been widely adopted for low temperature annealing of cold reduced or pack rolled piled sheets and for box annealing of steel in coil form. The equipment comprises a number of fixed bases on which the material is stacked, together with portable heating covers which can be transferred from one box to another by an overhead crane. Two, three or four bases are used with each heating cover. The charge is protected from oxidation during the entire annealing cycle by a thin steel inner cover which is sand-sealed at the base.

Two developments in the materials available for the construction of furnaces made the design of " top-hat " or cover furnaces a practicable possibility. The first was the manufacture of heat-resisting steel sheets and the satisfactory welding of these sheets to form a thin and light-weight inner cover which replaced the heavy covers constructed of mild steel 1 in. to 1¼ in. thick used in the older types of furnaces. This also made possible higher thermal efficiencies in the older types of furnaces, but the working life of these light-weight covers was not too good because of flame impingement, poor temperature control and distribution.

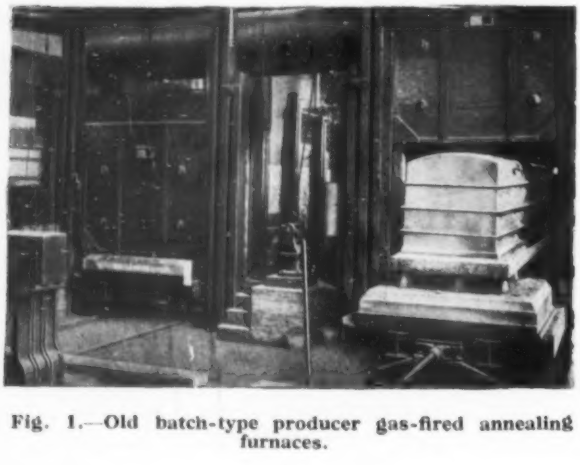


Fig. 1.—Old batch-type producer gas-fired annealing furnaces.

It should be appreciated that the majority of the older " in and out furnaces " and tunnel furnaces are heated by hot producer gas or coal, so that the same control of flame conditions is not possible as in the modern furnace heated by coke oven, town or clean producer gas. The use of light-weight and thin steel inner covers gives tremendous advantages since the lighter weight requires less fuel and the heat transfer is more rapid from the outside to the inside, making a reduction of external temperature possible.

The second development which made possible the construction of cover type furnaces was the progress in the manufacture of refractories. For many years furnaces could only be built of firebrick because no other more suitable material was available. With the introduction of diatomaceous insulation, it was possible to reduce the loss of heat by radiation but only at the expense of an increase in the heat storage capacity of the wall.

It was not until light-weight hot face insulating refractory was introduced that portable lift-off cover furnaces became economically possible. The lighter grades of this material are now used because of the heat saving by the reduction in the heat storage in the walls and due to the necessity of keeping the weight of the portable covers to a minimum to allow of lifting by existing overhead cranes.

When these furnaces were first introduced, use was made of gas fired radiant tubes arranged vertically or horizontally, the object being to provide a system of heating which would allow a protective atmosphere to be admitted to the charge and also to surround the outside of the inner hood containing the charge. This enabled a long life to be obtained from the inner hoods but with a greater fuel consumption than would be obtained with direct gas firing. It was some years before this was appreciated in America or in this country.

Portable cover furnaces are usually operated as follows : The charge of sheets or coiled strip is stacked on the base and the necessary controlling and recording thermocouples placed in position. The inner hood or cover is then placed over the charge and the lower edges sealed in sand or chrome ore powder. The protective atmosphere is then admitted and its pressure maintained until the end of the cycle when its charge is cooled below oxidation temperature. The outer cover already hot from

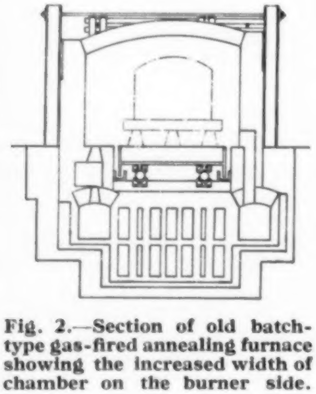


Fig. 2.—Section of old batch-type gas-fired annealing furnace showing the increased width of chamber on the burner side.

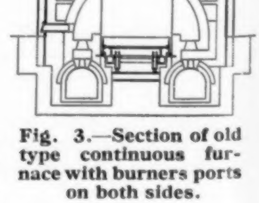
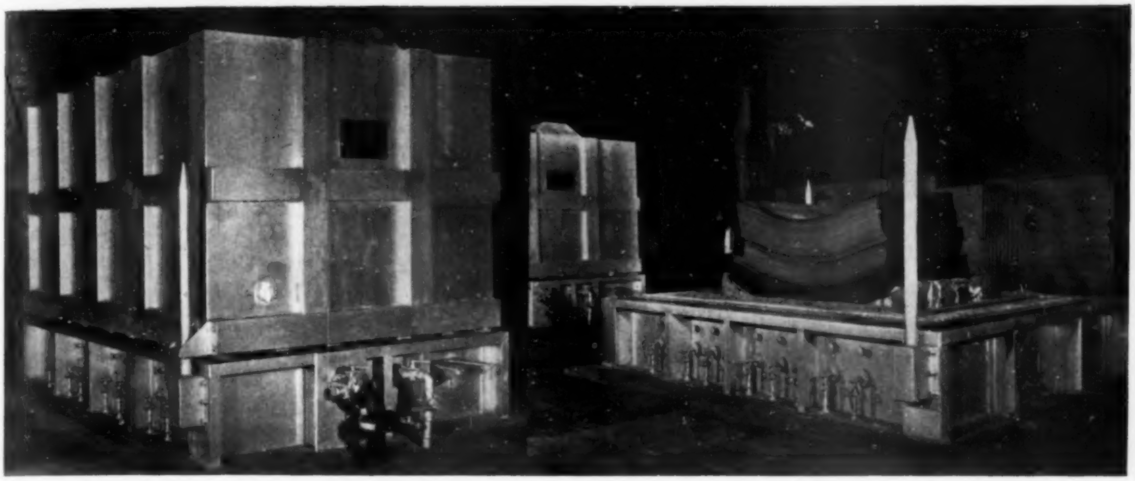


Fig. 3.—Section of old type continuous furnace with burners ports on both sides.



Figs. 4 and 5.—Showing the new design of portable cover annealing furnace for steel sheets. The complete furnace on the left and the base with a charge of sheets on the right.

its period of operation on another base is transferred by the crane and dropped over the inner hood. The gas burners are then lit and the heating up cycle commences. With vertical radiant tube furnaces the flames inside the tubes are at a maximum height at the beginning of firing and the top of the charge heats up at a faster rate than the bottom. When the temperature control instruments reduce the rate of gas consumption the height of the flames inside the tubes are gradually shortened which gives even heating from top to bottom of the charge. In furnaces having horizontal radiant tubes, the rate of gas consumption in the upper elements can be curtailed to give uniformity from top to bottom.

Heat Transmission

It is apparent that in both these radiant tube furnaces the greater percentage of heat transmission into the pack of sheets is from the sides with a much smaller percentage from the top and ends due to reflected radiation. T. J. Ess and J. D. Kelly have shown that the edgewise conductivity of piled steel sheets is about 3½ times the perpendicular conductivity due to the air or gas spaces between the sheets. While this shows conclusively the greatest proportion of heat transfer must be from the sides, every attempt should be made to increase the rate of heat transfer through other faces of the pack of sheets, i.e., the top, bottom and two ends.

With these requirements in view, The Dowson and Mason Gas Plant Co. have recently designed a new type of portable cover annealing furnace which is shown in Figs. 4 and 5. This is direct gas-fired in that no radiant tube elements are used, but the burners are arranged on the two longitudinal sides of the heating cover. The spacing of the burners causes an almost continuous curtain of flame on either side of the inner cover which commences at a point well below the base of the pack of charged sheets. The sides are therefore heated by direct radiation from highly luminous flames spaced much closer together than is possible with any type of radiant tube. The rate of heat transmission by radiation is materially increased, but, in addition, the sides of the inner cover receive heat by convection.

In radiant tube furnaces, the space between the top of the inner cover and the underside of the arch of the heating cover is often limited to a few inches. It is probable this prevents the top of the charge from heating up too fast, which might occur if the space was greater and allowed the arch to receive more heat from the radiant tubes.

In the radiant tube furnaces, the ends of the pack only receive heat by reflected radiation, whereas in the new direct fired furnace the waste gases pass down the two ends thereby increasing the rate of heat transmission by adding convection to the transfer by radiation. Some American designs of direct fired furnaces have made a prominent feature of the concentration of heat at the bottom of the charge where it is badly needed. The claim is made that the top of the charge will take care of itself when heat is driven to the bottom of the furnace. No attempt is made to obtain true bottom heating and the gases are exhausted directly through the arch of the hood.

Down-draught Recuperator

Experience in this country has shown that of the older box type annealing furnaces the most satisfactory have been the recuperator down-draught types with exit flues in the hearth. The new design referred to here is a return to the well-tried basic principles of annealing furnace design, but with modern burners, temperature controls and recuperators.

Instead of an unheated refractory base, which is a feature of most American designs, this furnace makes use of a cast steel pan similar to those used in the older in and out box-type furnaces. The charge of sheets is loaded on the pan and covered with the inner hood. The pan rests on firebrick piers thereby allowing the passage of hot gases under the charge and increasing the rate of heat transmission where it is so badly needed.

In nearly all radiant tube or direct fired portable annealing furnaces the combusted gases are exhausted at an appreciably higher temperature than the temperature of the sheets being annealed. This is because recuperator systems have not generally been incorporated in these furnaces. In this improved design use is made of small diameter thin-walled metallic recuperator elements to pre-heat the air for combustion with

the waste gases. The method of mixing the gas with the pre-heated air results in flames of high luminosity which materially helps in the transmission of heat.

The additional features incorporated in the furnace enable the charge to be heated at a faster rate, with a better temperature uniformity and a smaller consumption of gas than is possible with other types of portable cover annealing furnaces.

Metallurgical advantages are implicit in the close temperature control obtained while the reduction in heating time made possible by improved furnace design decreases the liability to stickers.

Gas Carburising with Town's Gas

By D. S. Laidler, B.Sc., Ph.D. A.R.I.C., A.I.M.

Messrs. Wild-Barfield Electric Furnaces Limited.

The application of the theories of diffusion of carbon into iron and steel has been studied over a long period in efforts to develop methods of carburising which permit complete control. Investigations have covered a wide range to arrive at the simplest and most economical atmosphere, and in this article the author describes the success achieved with town's gas and gives some results obtained.

THE carburisation of steel, one of the oldest of metallurgical processes, has long been carried out with solid agents, and although the use of materials rich in carbon with suitable energisers such as barium carbonate is still widely practised, in recent years it is being superseded by gas-carburising methods, particularly for large components requiring relatively deep cases, where production commitments are heavy, and precise control of the case depth and type is essential.

It is only by the use of such methods of carburising where complete control is possible that one is enabled to apply the theories of diffusion of carbon into iron and steel which have long been the subject of investigation. The earlier attempts of Runge,[1] Tamman and Schonert,[2] Bramley and co-workers,[3] to interpret carburisation in terms of Fick's Law of Diffusion were emphasised by the later work of Wells and Mehl,[4] Pasche and Hauttmann,[5] Harris,[6] and Taylor and Laidler,[7] where the effect of steel composition and impurities, carbon concentration and temperature changes on the diffusivity coefficient are studied. The chief variables which affect the rate of carburisation are :—

(i) *The initial carbon content of the steel.*—Naturally all other things being equal, the lower the initial carbon, the higher the rate of carburisation.

(ii) *The diffusivity coefficient.*

(iii) *The saturation concentration of carbon in austenite.*—The presence of alloying elements affects this value, nickel to a marked extent.

(iv) *The catalytic activity of the steel on the carburising reaction.*—This factor is most important where the rate of carburisation is less than the theoretical maximum.

(v) *Temperature.*—This is the major factor and the importance of small temperature variations cannot be over-emphasised.

(vi) *The composition of the carburising gas.*—This influences the equilibrium concentration of carbon in austenite, the rate at which the gas reacts to form atomic carbon, and the physical nature of the graphitic carbon or soot which is derived from the atomic carbon. Some scaley forms of soot are excellent "stopping-off" media when deposited on the work and are thus to be avoided.

(vii) *The rate of flow of the gas.*—In many commercial gases this is decisive as a delicate balance is attempted between a rate and ratio which does not give undue carbon deposition on the one hand and which does not under-carburise on the other hand. The corresponding consideration in pack carburising may be considered as the influence of the added "energisers" and in liquid carburising such factors as the "strength" of the bath.

The solution of Fick's Law most widely applicable to carburisation is :—

$$1 - \frac{C}{C_0} = \frac{2}{\sqrt{\pi}} \int_{0}^{\frac{x}{2\sqrt{DT}}} e^{-y^2} dy.$$

where C is the carbon potential at a distance x from the surface, Co is the carbon potential at the surface, D the diffusivity constant, T the carburising time, and e^{-y^2} the Gauss error function. From this equation a solution can be obtained to show that the case depth is proportional to the square root of the carburising time when the surface carbon potential and diffusivity coefficient are constant. The importance of this relationship is often overlooked, and case depths given in terms of "x thousandths of an inch" in the first hour and so on, whereas it should be emphasised that, for example, to attain a depth of 0·080 in. requires four times as long as for 0·040 in. The interpretation of such facts into engineers' specifications is, of course, intimately connected with an appreciation of the precise control of case depth and type of case, together with the minimising of distortion and subsequent small grinding tolerances associated with the practice of gas carburising.

Intimately connected with these observations is the question of measurement and interpretation of case depth which is usually carried out in industry by one of the following methods : (1) Visual measurement of the hardened zone on a quenched and fractured test piece ; (2) sectioning—i.e., taper grinding a hardened specimen ; (3) annealing a test specimen and measuring the case on an etched microsection ; (4) taking accurately

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1 Runge, I., *Zeit anorg. Chem.*, 1921, **115**, 293.

2 Tamman, G., and Schonert, K., *Stahl u. Eisen*, 1922, **42**, 654.

3 Bramley, A. and co-workers, Iron and Steel Inst. Carnegie Memoirs, 1926, **15**, 17 ; 1926, **15**, 127 ; 1927, **16**, 35 ; 1928, **17**, 67 ; 1929, **18**, 1. Bramley, A. and co-workers, *Trans. Far. Soc.*, 1935, **31**, 307.

4 Wells, C., and Mehl, R. F., *Amer. Inst. Min. Met. Eng.*, 1940, 1,180.

5 Paschke, H., and Hauttmann, A., *Arch. Eisenhuttenw.*, 1935, **9**, 305.

6 Harris, F. E., *Metal Progress*, Aug., 1943, 265 ; May, 1944, 683 ; June, 1944, 1,111 ; Sept., 1944, 488 ; Jan., 1945, 84 ; April, 1945, 713.

7 Taylor, J., and Laidler, D. S., Private communications, 1940–44.

Fig. 1.—Part of a Wild-Barfield prepared town's gas carburising installation showing furnace and retort.

measured turnings and analysing quantitatively for carbon content. Of these, the only really accurate and reliable method, particularly when dealing with alloy steels, is the analytical one, but, of course, it is too laborious for a standard procedure. The work of Grossman,[8] Harris (*loc cit*) and other American authors, and that of Taylor (*loc cit*) in this country, has all contributed largely towards a suitable technique.

The application of the above important principles underlying the diffusion of carbon into iron and steel has been carried further to enable the type of case produced to be as readily controllable as the case depth. When active carburisation is stopped, and diffusion is continued by soaking at the same temperature in a neutral atmosphere, the diffusion is no longer represented by the equation given previously but by the following equation used by Bramley and derived by Carslaw:[9]

$$C = \frac{H}{2\sqrt{\pi DT}} \cdot e^{\frac{-x^2}{4DT}}$$

where H is a constant related to the amount of carbon diffusing. From this it has been possible to derive values of the ratio $\frac{T}{t}$ (where T is the total time at temperature, t the active carburising part of T, and (T-t) is the diffusion time) for any given steel at any given temperature to result in any final desired surface carbon content. In brief, the depth of any case is dependent on the time and temperature for any given steel, always provided that carburisation proceeds at the maximum rate (i.e., available carbon in a suitable form is supplied to the steel surface equal to or faster than the rate of diffusion into the steel), while the quality of the final case (i.e., the carbon gradient) can be closely controlled by the $\frac{T}{t}$ ratio.

Thus it may be summarised that the main advantages of gas carburising over pack methods are as follows :—

(*a*) The possibility of more precise control of temperature as the parts are not packed in a solid compound. It has already been seen that small variations in temperature greatly effect control of both the case depth and the type of case.

(*b*) As the prime cost of carburising is the heating of the material, it follows that considerable economies are effected by not heating any solid compound together with the much shorter carburising cycles obtained by the practice of carburising at temperatures of the order of 925°–950° C. and diffusing out the hypereutectoid formed at these elevated temperatures.

(*c*) Difficulties of handling large amounts of solid carbonaceous compounds are eliminated.

(*d*) The type of case produced is much more satisfactory as examples given below will demonstrate.

Practical methods of gas carburising are now well established in industry, and in the U.S.A. one may conveniently divide the methods as follows :—

(i) *Natural gas.*—This may contain as much as 80% methane and 10% of ethane and propane, and is usually diluted with air or partially burnt gas which is substantially CO and N_2.

(ii) *Bottled or liquefied hydrocarbons.*—Propane and butane are most commonly used when mixed with a diluent gas, but the dangers of excessive sooting have been emphasised by Cowan[10] and others.

(iii) *Liquid hydrocarbons.*—Such hydrocarbons as dipentene, aniline, etc., are admitted into the carburising chamber in controlled amounts and turbulence introduced by a fan to counteract the great soot-forming tendencies of these hydrocarbons.

The advantages of "natural" gas being absent in Britain, the choice of a medium lies between bottled or liquid hydrocarbons and town's gas. The most commonly used bottled gases are propane or butane diluted with such media as charcoal burner gas, burnt or partially burnt town's gas, air, or raw town's gas. Unfortunately it is a characteristic of these hydrocarbons that they crack on steel surfaces at temperature, giving rise to carbon deposition in the form of a tough adherent scale which accumulates in the retort and in addition can act as an effective "stopping-off" agent. To overcome such tendencies the gas is usually diluted to an extent which gives rise to carburisation proceeding below the maximum possible rate.

Many attempts have been made to utilise raw town's gas with various additions or treatments for gas carburising, including those of Darrah[11] and other workers,[12] but have met with only varied success, probably due to the failure to appreciate the necessity for virtually complete removal of the undesirable decarburising constituents CO_2, O_2 and H_2O. The method illustrated by the installation shown in Fig. 1 employs raw town's gas only without additions of hydrocarbon gases, but the decarburising constituents have been removed without serious destruction of the methane, one of the best carburising agents.[13] The gas preparation unit consists of a catalyst in which the CO_2 and O_2 are removed, simple

8 Grossman, M. A., *Trans. Amer. Soc. Met.*, 1938, **26**, 427.
9 Carslaw, H. S., "Introduction to the Mathematical Theory of the Conduction of Heat in Solids," Macmillan, 1921, p. 153.

10 Cowan, R. J. *Trans. Amer. Soc. for Metals*, 1937, xxv, p. 843.
11 Darrah, W. A., *Ind. Eng. Chem.*, 1941, **33**, 54.
12 *Industrial Gas Times*, 1941, **5**, No. 49, p. 3.

air coolers prior to the silica gel containers where the moisture is removed, with accessories such as a low pressure compressor to maintain adequate flow, and flowmeters of the direct-reading and integrating types. Typical examples of the inlet and exit gases from the preparation unit are :—

	CO_2	O_2	CnHm	CO	CH_4	H_2	N_2	H_2O
Raw Gas ..	3·3	0·6	2·1	16·4	24·0	49·5	4·1	1·5
Prepared Gas	0·0	0·0	0·6	20·2	23·6	51·2	4·4	0·0

This prepared gas has the advantage of cheapness, ease of production, the elimination of addition of bottled gases, and more particularly of the control of carburising which is made possible by having an atmosphere which does not deposit scaley carbon on the work being carburised no matter how great is the gas flow in excess of theoretical requirements. This enables a charge to be purged and loaded, and with the flowmeter reading a constant but not critical amount (200 cu. ft./hr. in the case of the large installation shown which is capable of holding 15 cwt. of work at a time) no further attention is required until the end of the calculated active carburising period (t) has been reached, when the flow is stopped and the two retort valves closed to enable the work to remain in the static protective atmosphere for

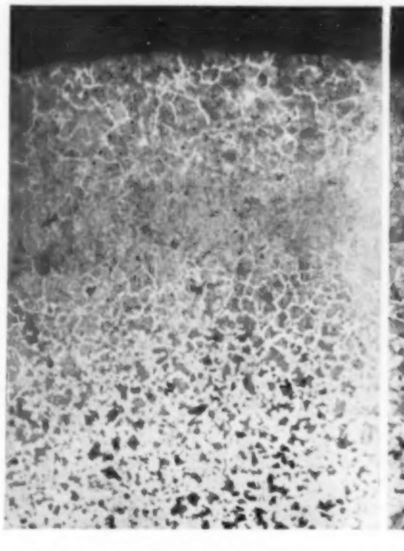


Fig. 3 (a) Mild steel gas carburised to a depth of 0·080 in. at 925° C. × 50 No diffusion period. Note free cementite.

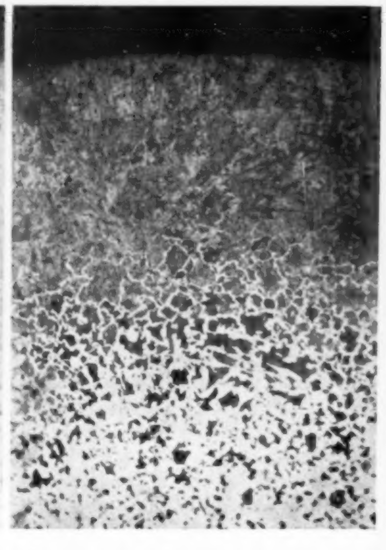
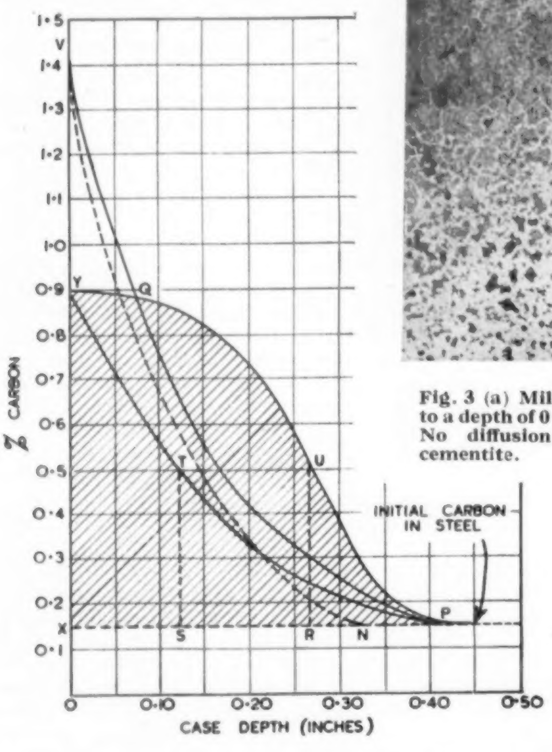


Fig. 3.—(b) Mild steel gas carburised to a depth of 0·080 in. at 925° C. × 50 Diffused to eliminate free cementite.

diffusion of the high carbon case. The acquisition of such an atmosphere enables extremely close control of case depth and type of case to be attained in a very much shorter period than other methods, as will be ascertained from a study of the graphs shown in Fig. 2 or the photomicrographs, Fig. 3. In Fig. 2, the curve YTP is typical of a carbon gradient achieved by straight carburising to attain a total case depth of 0·040 in. on a mild steel. For most carburising applications a surface carbon content of 0·9% for mild steel is the maximum which can be tolerated, particularly when the component has many sharp splines or teeth where free cementite can build up. To avoid exceeding this figure of 0·9% on mild steel (the figure is somewhat lower for some alloy steel—e.g., for the popular En.39 (S.82) steel it is 0·75%) it is necessary to carburise at a temperature lower than 925° C., usually of the order of 880°–890° C., if carburising at the maximum possible rate for the given temperature. Alternative methods are to carburise at 925° C. with a weak carburising medium, or to grind off the hypereutectoid layer formed by carburising at the maximum rate at 925° C. when the carbon maximum reaches 1·4%. All three alternatives have their obvious disadvantages—namely, (i) carburising at 880°–890° C. is very much slower than at 925° C.; (ii) carburising with a weak medium can lead to uneven carburisation in the less favourably disposed parts of a charge, and in



Curve VQP Straight carburisation at 925° C. for 0·040-in. case for T hours. (Area enclosed by VYQ represents hyper-eutectoid).

Curve YQP—Diffused case from VN (VN obtained in active carburising time, t) in T hours, after soaking T-t hours.

Curve YTP—Straight carburisation to arrive at 0·9% surface carbon (taking a much greater time than T hours, as temperature has to be lower).

Area YTSX represents hardenable part of case in YTP.

Area YQURX represents hardenable part of case in YQP

Fig. 2.—Comparison between diffused case and that obtained by straigh: carburisation.

13 Wild-Barfield Electric Furnaces, Ltd., Haywood, F. W., and Laidler, D. S., British patents granted and pending.

addition requires longer time cycles, and (iii) grinding off a hypereutectoid layer often leads to surface cracking, leaves a case which decreases very rapidly in carbon content, and is wasteful of carburising time and materials.

The curve VQP represents the gradient obtained by active carburising at the maximum rate of 925° C., the 0·040-in. case naturally being achieved in a very much shorter time than the curve YTP. It is, however, quite unsatisfactory due to the excessive hypereutectoid present. If, however, the time taken to produce this case (T hours) is suitably sub-divided into an active carburising period (t) and a diffusion period (T-t) as already described, then the dotted curve will represent the state of the case after hours, which diffuses out by the end of T hours to the curve YQP with all its attendant advantages.

The photomicrographs in Figs. 3a and 3b show respectively an 0·080-in. case which has not been diffused (i.e., a maximum carbon value of 1·4%) and one which had the same time at temperature, but this was divided into the appropriate active and diffusion times. Although greater in depth, these two photomicrographs illustrate the types of carbon gradient in the curves VQP and YQP respectively in Fig. 2. The case would be obtained in a total time (T) of 9 hours which compares very favourably with pack carburising methods taking three to four times this time and producing a less satisfactory type of case. These facts together with the much more desirable type of final case and the minimisation of distortion represent a considerable advance in carburising technique. The proportion of the case produced by this method which is of eutectoid composition enables a considerable grinding tolerance to be allowed without any loss of hardness, which is much more satisfactory than attempting to grind off a hypereutectoid type of case with its consequent danger of developing cracks. Usually, with a mild steel carburised at 925° C. and subsequently diffused, at least half of the total case is eutectoid, while when carburising and diffusing at 950° C. the proportion may be as high as 70%.

The precise control over the carburising reaction which obtains in such a method, in addition to giving much faster carburising and a better type of case, enables a furnace of the size illustrated to cope with the carburising output of a large number of pack carburising furnaces, thereby effecting important advantages in shop space and cleanliness as well as in initial outlay and running costs.

No review of carburising practice would be complete without reference to the prevention of carburisation or "stopping-off" process. While many proprietary compounds such as clays, paints, etc., are proving extremely useful in industry, none can completely withstand more severe conditions than copper plating of the first quality. The importance of the physical characteristics of the plating cannot be over-emphasised, and properties such as non-porosity have a more important function than mere thickness of plating. Given ideal conditions, the efficiency of the coating should be proportional to the square root of the thickness, and, in general, a thickness of 0·002 in. is adequate for "stopping-off" cases of the order of 0·040 in.

The author is indebted to the Directors of Messrs. Wild-Barfield Electric Furnaces, Ltd., for permission to publish the information contained in this article, and to Messrs. Rolls-Royce, Ltd., for permission to reproduce the photograph shown as Fig. 1.

Isothermal Quench Furnace for Cyclic Annealing

The Ajax Electric Company, Philadelphia, Pennsylvania (Associates of Electric Resistance Furnace Co., Ltd., Weybridge, Surrey, England), working with several automobile manufacturers, has further extended the scope of interrupted quenching operations to include the cyclic annealing treatment of alloy steel forgings. Utilising its residual heat as it comes directly from the press the forging is introduced into a salt bath operating at the sub-critical transformation temperature for the particular steel where it remains for sufficient time (indicated by the "S" curve for the particular steel) to permit complete transformation to occur, after which it may be removed and cooled. This method not only anneals the forgings with extreme uniformity but also removes all traces of scale. The entire process requires only 10–60 minutes compared with 5–25 hours needed with the conventional annealing methods. The degree of annealing can be controlled within very close limits so as to produce a structure offering optimum machineability qualities. In addition all scale is removed in the process.

Large savings have been effected due to the following advantages produced by this new cyclic annealing process: (1) Negligible furnace operating costs as compared with the conventional methods because cyclic annealing involves the extraction of heat only; (2) reduced time cycle requiring only minutes compared with hours formerly necessary; (3) improved machineability, smoother surfaces, and elimination of tearing because of the more uniform structure produced; (4) elimination of shot blasting and all handling incident to cleaning operations; (5) reduced floor space requirements; and (6) reduced amount of work in process.

Since the residual heat of the forging must be extracted rapidly to assure the absolute uniformity and accuracy of this cyclic annealing treatment, the new Efco-Ajax isothermal quench furnace for cyclic annealing has been designed especially for this process. The use of a motor operated mechanical agitator avoids temperature build-up in the bath while maintaining it at a constant temperature, and provides uniform and maximum quenching speed to each individual piece of work introduced into it. Ajax engineers have designed mechanisms especially adapted for conveyorizing the entire cyclic annealing process. With little or no labour, the hot forgings are received from the forging press, loaded into and out of the salt bath furnace, quenched and cooled—all in automatic sequence. These mechanised units in most cases are compact enough to be placed alongside the forging presses in most forge shops.

Errata

On page 326, April issue, right hand column, the symbol W has been omitted from the sub-heading: Discussion of T. R. Cunninghams' Procedure . . . . . (approx. 0·6% present) should read (approx 0·6% W present) in 18/8 Mo steels.

Some Recent Heat-Treatment Furnace Installations

The design of heat-treatment furnaces whether for general or particular heat-treating operations will probably always be a compromise between theory and practice. So many factors are involved that perfection is never likely to be attained, but progress is continuous and although the changes effected in relatively short intervals may not show many outstanding development, a comparison with heat-treatment furnaces used a decade or so ago clearly indicates progress of a high order. Some of the more recent installation are briefly described.

IN the broadest sense heat treatment embraces all processes which involve heat by which the physical and mechanical properties of metals and alloys are affected ; it can therefore be said to be associated with practically all the processes involved in converting the ores into finished metal components. In this article the consideration of recent plant is confined to heat treatment operations, which either produce in the material the final structure required in the completed component or permit its more easy working. Additional refinements may also be desirable, such as a bright or clean finish on the material treated, in which scaling decarburisation, and other chemical reactions are eliminated from the heat treatment process. Such refinements frequently have economic advantages, since they may entirely eliminate secondary cleaning operations. However, satisfactory results in achieving the main object depends upon the equipment, the material or component, and those responsible for carrying out the heat treatment operations.

This subject of heat treatment is so important that there is justification for the statement that its study is often of more practical importance than the search for new alloys, bearing in mind that the useful effect of the addition of new elements is generally almost entirely dependent on a heat treatment, without which the results would be of little interest. While the process of heat treatment, in its narrower sense, is applied to modify the structure and constitution of the metal by controlling the heating and cooling conditions under which changes in the solid state occur, all the properties desired are not improved by a particular process. Thus, as a rule, a compromise must be effected to develop the most desirable properties in a material for a specified purpose. With the design and type of furnace equipment too, the choice is frequently a compromise between that which is considered to be best in theory and one which, when considered in conjunction with the conditions imposed, is practical.

Although many factors are involved in the design and operation of heat treatment furnaces, the value of the result desired has an important influence in determining the type. The cost of the heating medium employed, temperature and atmosphere control, and other phases in heat treatment operations are really incidental to the main consideration, which involves the quality of the treated product or component and its overall cost. Thus, in making a choice of heat treatment equipment, it is important to keep in mind the need for producing a high-grade product at low cost, using that form of heating medium and that type of equipment which will give these results under the conditions that operate in the particular works at which the installation is contemplated. The furnace must give satisfactory service, as to the degree of uniformity of heating, consistent with possible variations of output and conditions imposed by the shop requirements. For those products to be heated for treatment in their final stages of manufacture, there is a standard of accuracy of temperature and uniformity, a degree of reliability and ease of control, that may not be attainable except with the most refined and elaborate methods. In such cases the actual cost of heat units used in a furnace is secondary to the essential needs of attaining the required standard of quality of product, since the cost of failure to satisfy this standard consistently far outweighs the the small increment in cost in the actual energy applied, and the capital charges involved in the provision of more complicated equipment.

Types of Furnaces

Most heat treatment processes are carried out in batch, semi-continuous, or continuous operating furnaces. The batch method, with or without a removable charge container, was developed first, although, apart from the box-type heating chamber, there is no real comparison between modern batch type furnaces and the early types. These furnaces will always be popular because of their adaptability to many products varying widely in size, quantity, and even type of treatment. When the output of a product requiring the same heat treatment is fairly constant, an opportunity is provided for using some time of furnace in which the material to be treated is automatically handled, involving continuous heating and cooling operations. Between these two types there are various designs which are intermediate and can be regarded as of a semi-continuous character. In addition to temperature control, and in many cases atmosphere control, continuous furnaces have time-cycle control and are designed to repeat accurately a required treatment with a view to obtaining uniform products. Some more recent examples of these furnaces are briefly described in the following notes.

Gas Carburising Furnaces

Notable progress has been made in gas carburising and, although it is referred to elsewhere in this issue, reference to it should not be omitted in this review. In the case-hardening process, by which components machined from low-carbon steels are given a high-carbon surface layer or " case " to increase the wear-resistance, it has long been the accepted practice to pack the parts with solid carbonaceous material or

Fig. 1.—Birlec gas carburising equipment comprising three vertical pit furnaces—retorts, gas atmosphere plant and suitable loading jig.

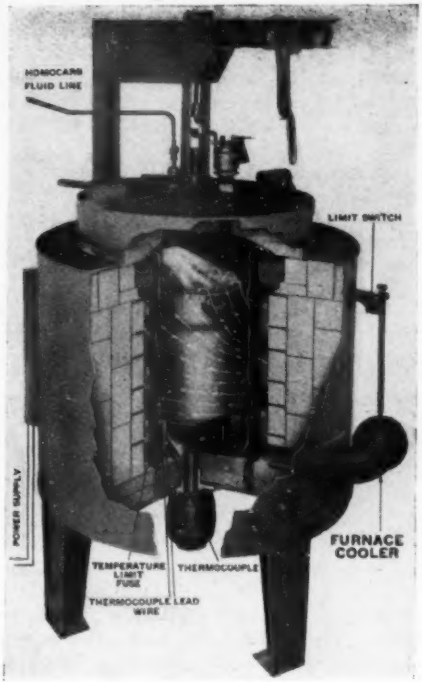


Fig. 2.—The Homocarb furnace which employs the drip-feed method for producing the carburising atmosphere.

"compound" in luted boxes, which are subsequently heated for prolonged periods in open furnaces. Pack-carburising, as this is termed, has many disadvantages, of which the most outstanding is the poor thermal efficiency inherent in the process. Gas carburising by comparison enables the application of a vastly improved procedure which is cleaner, quicker and a more economical method, permitting that precise degree of control demanded by present heat treatment specifications.

In pack carburising, the proportion of useful work in the total charge rarely exceeds 30% and is often as low as 15%, the balance being made up by the boxes and compound. On the other hand, in gas carburising, the percentage is never less than 70% and is usually higher, since no boxes are used, and only light trays or fixtures are needed to support the work. This great reduction in amount of dead weight results in more rapid heating to temperature with correspondingly lower fuel consumption. Overall time cycles are thereby reduced and thermal efficiency improved. In addition, the whole charge in the Birlec plant, shown in Fig. 1, is heated to temperature before the carburising gas is admitted, consequently carburising starts at the same time at every point in the charge. This feature gives a higher degree of control over case depth and uniformity than is possible with the older method. Then, by control of gas flow and composition or, alternatively, by employing the technique of "diffusion" periods, the carbon content of the case can be regulated in a manner which is quite impossible with pack carburising. This permits higher carburising temperatures without the fear of excessively high carbon contents, and thus further shortens the time cycle for given case depths.

Further advantages accrue as a result, the work being loosely loaded on light charger-carrying structures, with easy arrangements for oil quenching. Alternatively, by use of water-jacketed or insulated cooling chambers, any controlled rate of cooling can be employed; by shortening the carburising cycle, and eliminating boxes and compound, the floor space for a given output of carburised work is greatly reduced; labour requirements are less, and cleanliness and working conditions improved; and the final result is a marked saving in operating cost, coupled with a higher quality product and fewer rejects.

The gas carburising furnaces developed by Birlec Ltd. fall broadly into three categories: stationary batch types, rotary drum batch furnace types, and continuous types. Of the batch types probably the most practical is the vertical pit furnace, shown in Fig. 1 with retorts, gas atmosphere plant and suitably loading jig. These furnaces are built in a range of sizes of which the most popular has a work chamber 22 in. diameter by 36 in. deep and can accommodate a net charge of between 500 and 1,000 lb. of work. In all but the smallest types, a circulating fan is fitted in the bottom of the chamber, which, in combination with a baffle, forms a circulating system feeding gas to every part of the charge. Small and medium sized furnaces are electrically heated and are built with a cast alloy muffle or pot, which is an integral part of the furnace structure, only removed at occasional intervals for maintenance purposes. The largest sizes have no muffle, the chamber being lined with special refractories; and heated by gas-fired radiant tubes.

The rotary-drum batch furnaces consist of a work chamber in the form of a heat resisting alloy drum, closed at one end by a fixed insulated plug and at the other by a removable bung, which is withdrawn for charging and discharging. The drum is mounted horizontally on rollers and provision is made for rotation at a suitable speed between $\frac{1}{2}$ to 3 r.p.m. Carburising gas is introduced through a glanded inlet at the back of the furnace and the outlet is through the bung. The operating principle is similar to that for the pit-type furnace except that no charge-carrier is needed. This type of furnace is only suitable for work which will

withstand constant tumbling at the carburising temperature. Its main fields of application are for small light components such as links, rollers, collars and washers, etc., and for heavier components such as roller bearing races and roller gudgeon pins and similar articles of robust form and with a fairly heavy final grinding allowance.

Where large outputs of components of similar case depth have to be accommodated, continuous furnaces offer such advantages as: Maximum uniformity of treatment from piece to piece, with less dependence on the human factor; less labour required for furnace operation; ability to cool the work without contact with air, thereby improving surface finish; and automatic direct quenching, in a number of forms, can be readily incorporated. These advantages are particularly marked on short-cycle operations for case depths up to 0·025 in.; on the other hand, the continuous furnace is less adaptable than the batch type, in that it is not entirely suitable for a wide range of case depths since the furnace must be emptied when the carburising cycle is changed and there is, consequently, considerable idle time.

The drip-feed method of producing the carburising atmosphere is employed in the Homocarb furnace, shown in Fig. 2, which is designed by the Leeds and Northrup Company and built by The Integra Co. Ltd. This is a completely integrated equipment for carburising which not only heats the load uniformly but generates its own carburising gas from the hydro-carbon fluid supplied under controlled conditions. At the end of the soak, during which time the carburising gas is forced through the charge in alternating directions under close time and temperature regulations, the charge is cooled uniformly in the equipment until it is ready for transfer to a cooling unit or quench tank.

A complete continuous gas carburising plant, recently installed by The Incandescent Heat Co. Ltd., is shown in Fig. 3. The complete installation consists of a controlled gas atmosphere preparation plant, operated on the endothermic principle, a gas-sealed furnace of the continuous pusher type with pre-heating carburising and cooling zones, and return track for the cast nickel chrome work carriers, which may also be employed as a loading station. In practice, the work is progressed through the pre-heating, carburising and cooling cycles, supported on the nickel chrome carriers by means of the intermittent pusher operation. The furnace itself is heated by spirally wound metallic radiant tubes, which have improved considerably the efficiency of radiant heating by gas. The actual plant illustrated has been designed for the case hardening of driving pinions and gears to a depth of ·040 in.–·050 in. for the motor car industry, giving an output in the region of 200 lb. of work per hour.

Bright Hardening Furnaces

Much attention has been given to the use of controlled atmospheres for the bright hardening process. While the controlled atmosphere furnace prevents scaling, a film of discolouration occurs on the work when it is removed from the furnace, due to contact with the outside air. Discolouration does not matter on tools and dies, but its prevention is advantageous on springs, stampings, and similar small parts which are difficult to clean. A new Efco Lindberg tilting hearth furnace has been designed to overcome this which makes it possible to bright harden such parts of relatively light section which are not damaged by dropping into the quench. Extremely light sections which are apt to cool below the critical, by contact with room air before quenching can be quenched direct from the chamber to assure 100% hardening results.

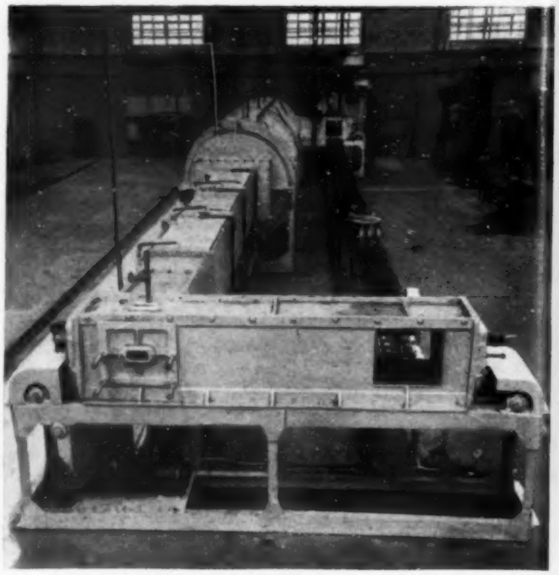
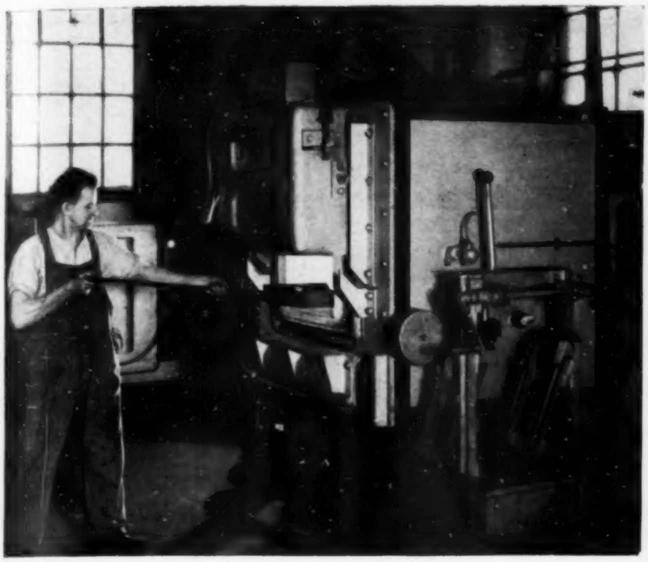


Fig. 3.—A complete continuous gas carburising plant

With this furnace the work is completely protected from the outside air, not only in heating, but in quenching too. The parts to be treated are placed on the manually operated hearth and heated through. The hearth is tilted and the parts drop through the chute into the quench directly below. The bottom of the chute extends into the oil, providing a seal against the outside air. Figs. 4 and 5 show the loading and discharging of this furnace which enable loads of several thousand parts to be bright hardened in such a way as to make it difficult to distinguish between the hardened and unhardened parts.

Annealing and Normalising Furnaces

For many purposes the use for heat treatment possesses advantages. The excellent heat penetration and soaking characteristics, coupled with absence of hard skin or spots, has caused both executives and operators to regard the use of solid fuel favourable. Its use has many disadvantages. Apart from the coaling and cleaning of fires, both of which affected furnace temperatures and conditions, the rapid development in alloy steels, which demanded specific and higher standards of heat treatment, gradually outpaced the capacity of the old types of furnaces, and the use of gaseous or liquid fuels, coupled with close temperature control and sometimes automatic temperature control, began to make headway in the industry. But the development of the automatic coal burning stoker, which can be controlled pyrometrically within very close and precise limits has changed the position and coal is increasing in favour. The normalising furnace shown in Fig. 6, which is fired by five automatic stokers is a case in point. It is designed to normalise alloy steel forgings and it was installed by Alfred Herbert Ltd. to meet very precise temperature conditions.



Figs. 4 and 5.—A new Efco Lindberg tilting hearth furnace for bright hardening small parts difficult to clean. Left: Loading work. Right: Unloading from quench tank.

Salt baths have been used for many years for heat treatment operations and a new and interesting method of annealing steel forgings has been named cyclic annealing. The principle consists in taking the forgings from a temperature above the upper critical, preferably directly from the hammer or press and quenching them in an agitated salt bath furnace operated in a temperature range of 620°–705° C., holding them at this temperature until transformation from austenite to soft pearlite is completed. The time required for this transformation will vary from ten minutes to one hour depending on the section and on the steel. Thereafter, it may be cooled in any manner desired without changing its hardness, which will range from 187 to 201 Brinell.

The advantages claimed for this new process is uniformity of structure produced—which facilitates the use of automatic turning and shaping machines; the production of clean and scale-free surfaces; reduced distortion due to elimination of residual stresses; the time cycle is reduced; less floor space is required; and substantial reductions in annealing costs.

An Efco-Ajax Hultgren salt bath furnace for this method of annealing is shown in Fig. 7 and it is claimed that thorough investigation on actual production lots of a variety of pieces of several different steels have developed such outstanding improvements in the quality of the finished products and such economies that one large motor car manufacturer has installed a completely mechanised plant to anneal the major component parts of its transmission.

G.W.B. Electric Furnaces Ltd. have recently installed several furnaces for the heat treatment of light alloy; including two pusher-type furnaces for pre-heating slabs prior to rolling into sheets. These furnaces are particularly large, having heating chambers 56 ft. × 12 ft. × 7 ft., ratings of 3,750 kws. and a combined output of 432,000 lb. per day. Another large equipment, for annealing coils of aluminium strip, is a twin-chamber batch-type furnace with each chamber 18 ft. × 9 ft. × 7 ft., which is serviced by a Gibbons–Van Marle charging machine. A completely new development is a conveyer type furnace for "flash" annealing of aluminium sheets or circles, as shown in Fig. 8. The main feature is a conveyer comprising small diameter

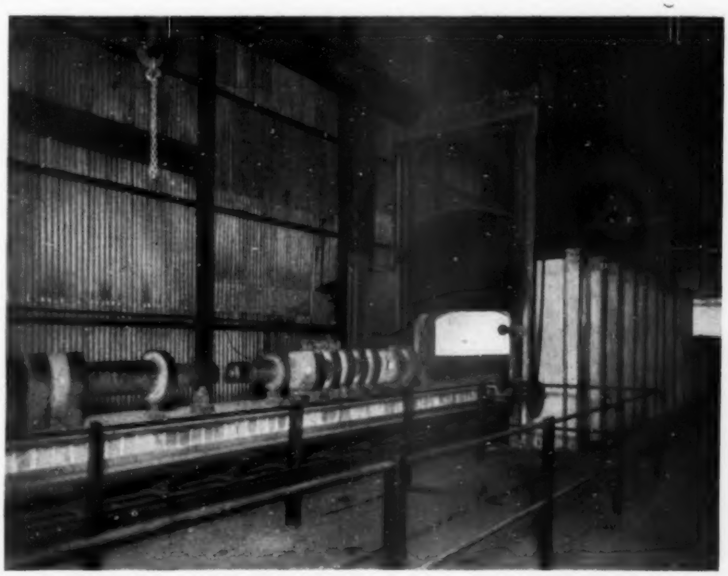


Fig. 6.—A normalising furnace fired by automatic stokers.

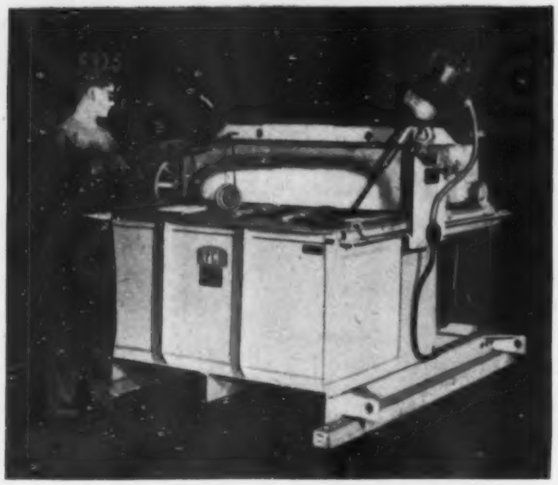


Fig. 7.—An Efco-Ajax Hultgren salt bath furnace for a new process of annealing.

wire ropes, reducing unproductive weight to a minimum. Other installations include continuous strand annealing furnaces for ferrous and non-ferrous wires, bell-type bright annealing furnaces, and pit furnaces for hardening and tempering tractor axle shafts.

The furnaces shown in Fig. 9 are of the pit type and were built by Siemens-Schuckert (Great Britain) Ltd., Brentford. The furnace body is sunk into the ground and the roof only is above floor level. After being raised clear of the furnace body, the roof can be moved to one side on rails. The furnace has a diameter of 6 ft. 9 in. and a depth of 8 ft. 10 in. The complete plant comprises seven furnaces of this type, which are used primarily for the heat treatment of aluminium alloy castings, stampings or forgings. The parts to be treated are placed, if very small, in baskets which are again placed on shelves of the charging container. If the parts to be treated are large then the use of baskets is not necessary.

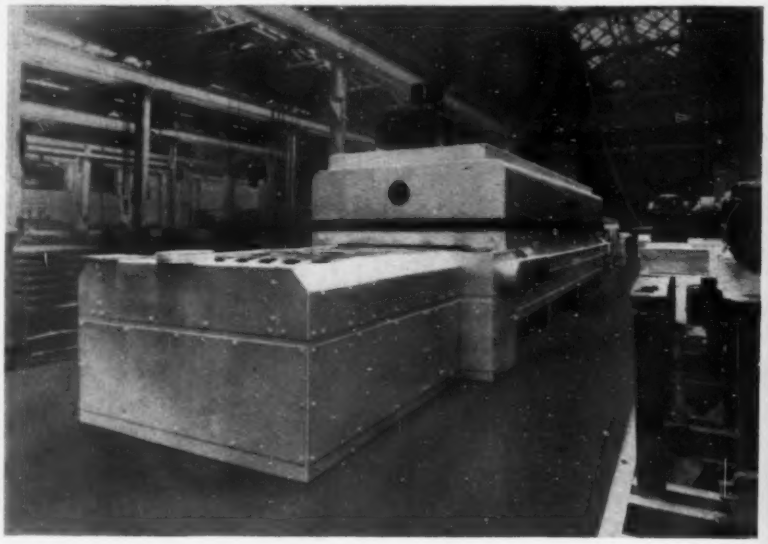
The furnaces have air circulation, the air being changed once per second in the furnace. The heat transfer is, thus, by means of convection and not radiation. Air circulation ensures very even temperatures throughout the furnace which operates at 530° C., a temperature which can be maintained to within ± 2° C.

Induction heating has made considerable strides in heat treatment applications and Fig. 10 shows equipment by Rediffusion Ltd. designed for annealing pen nibs for Wyvern pens. The application gear will handle many variations of nib size within certain maximum dimensions. Similarly, variations of power output and cycle time can be made. The process timer fitted in the heater illustrated is variable between 0 and 10 secs. The generator used is a Redifon model R.H.22, giving maximum of 350 watts. Working outputs on various nib sizes are of the order of 200–210 watts. The approximate temperature with 14 ct. gold nibs is 850° C. in 2 secs. This heater is a new model which retains the best features of earlier models and has many worthwhile improvements in operation and efficiency.

Gas Malleabilising

It has long been recognised that the present method of annealing malleable castings, by packing them in iron ore in heavy cans, is completely out of harmony with present-day efficiency. The Birlec patented process for annealing whiteheart castings eliminates entirely both cans and iron ore and reduces the annealing cycle to a matter of 48 hours or so (depending on the section) instead of five days or more as in the case of the conventional process. Overall operating costs are reduced to a fraction of those of the older method and working conditions are considerably improved.

Fig. 8.—A recently developed conveyer type furnace for "flash" annealing aluminium sheets and circles.



Courtesy of High Duty Alloys Ltd.

Fig. 9.—Part of a battery of pit furnaces for aluminium alloy castings, forgings and stampings with a charging container.

In comparison with pack malleabilising, the advantages of the process may be summarised as: The entire elimination of heavy cans and iron ore, resulting in rapid heating and improved efficiency; the marked reduction in the number of men and man-hours required to operate the system; a much shorter annealing cycle; an elevator furnace, in relation to the space occupied by a conventional annealing plant, will give a greater weekly tonnage per square foot of floor area; because of the foregoing advantages, it can be readily seen that the total operating costs are considerably reduced; working conditions are much cleaner, easier and healthier—by virtue of the absence of iron ore, the elimination of the packing and loading of heavy cans and constant attention to fuel-fired furnace; finally, the important feature of improved quality and uniformity of product. The surface finish is excellent, requiring little or no after-cleaning and there is no risk of "peeling." Ductility, machineability and freedom from distortion are maintained as good as, and often better than, with the pack annealing method.

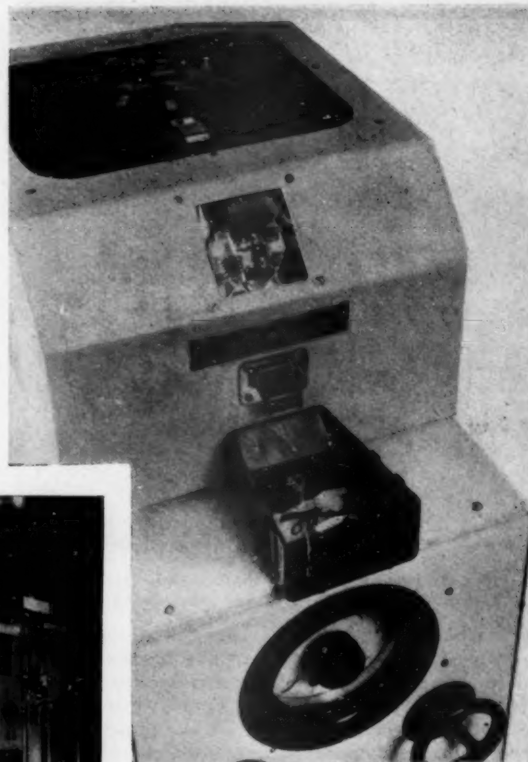
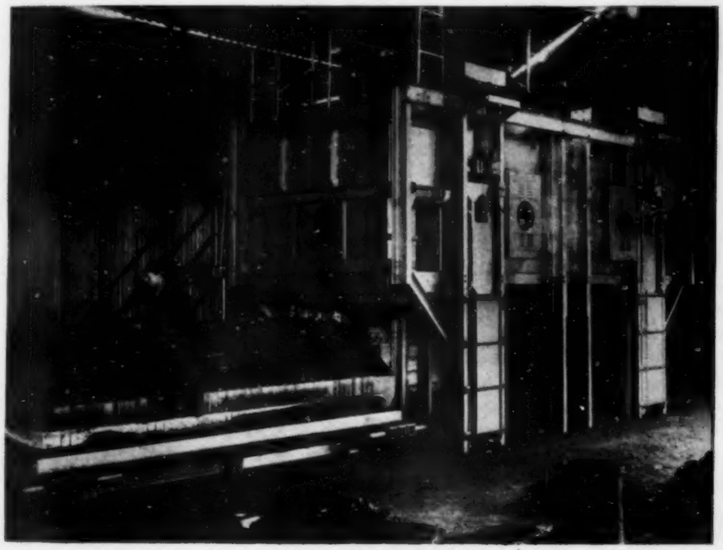


Fig. 10.—An induction heater used for annealing 14 ct. gold pen nibs.

Fig. 11.—A Birlec elevator type furnace for gaseous annealing, under Birlec patent, whiteheart malleable castings.



An elevator type furnace is adopted as shown in Fig. 11, the hearth of which is in the form of a removable bogie (two are supplied with each furnace) loaded at floor level and then raised into the furnace by a built-in electrically-operated hoist. Gas tight sealing is by means of a skirt on the furnace which engages a sand seal on the hearth. Circulating fans are fitted in the roof of the furnace and the charge is loaded on the hearth so as to allow free circulation of the atmosphere over all parts of the charge. In the illustration, one bogie with an annealed charge has just been removed from the furnace at a temperature of 600° C. and transferred to the unloading station. The second bogie, loaded in readiness, is now moved from the loading station to a position underneath the furnace and elevated into it by the hoist. The heat is switched on and the temperature control set to the annealing temperature (1,050° C.). During the heating-up stage, the atmosphere in the furnace is at first air, and in the early stages the oxygen of this air is absorbed by the castings resulting in a thin film of oxide, nitrogen being left as the main constituent of the atmosphere. As the temperature rises, this oxide film is reduced by the carbon in the castings with formation of carbon monoxide

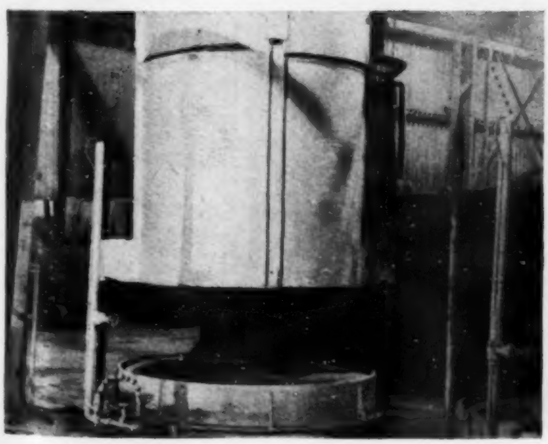


Fig. 12.—A small bell-type gas malleabilising furnace with a capacity of 4 cwt. charges of whiteheart castings.

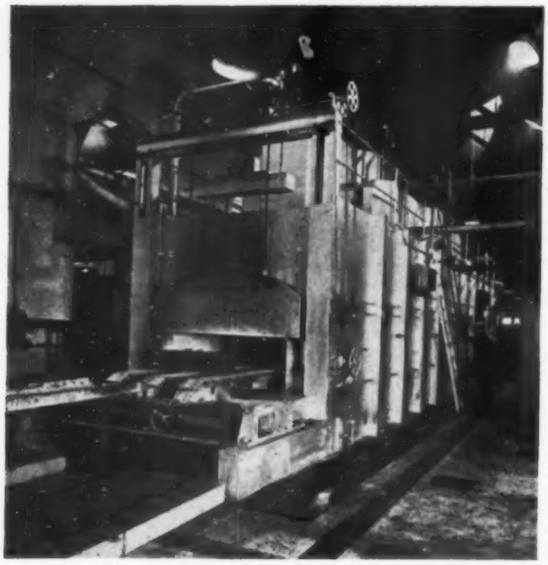


Fig. 13.—A recent furnace installation for tempering laminated springs in the assembled state.

and carbon dioxide, until, as full temperature is approached, the atmosphere consists mainly of nitrogen and carbon monoxide. The atmosphere circulating fans and decarburising air supply are then turned on, the air supply being adjusted to maintain the correct carbon dioxide content of about 6% to 7%.

At the end of the soaking period, the air supply is cut off, the furnace heating elements switched off, and the forced cooling system brought into operation. When the temperature has fallen to approximately 550° C. to 600° C. the bogie is lowered to the unloading station. The second bogie, after cooling to room temperature, has been unloaded, transferred to the loading station, reloaded, and is now ready to transfer to the furnace for the next cycle.

The success of this process turns on the exact control of the atmosphere in relation to the progress of the annealing cycle. Air for decarburisation is admitted to the circulation system by means of a small blower with a control valve and flow meter. A carbon dioxide recorder is fitted and the atmosphere control is made fully automatic by means of electrical contacts on this recorder, operating a motorised valve on the air supply. A small bell type gas malleabilising furnace by The General Electric Co. Ltd. is shown in Fig. 12; it has a capacity for 4 cwt. charges of whiteheart castings which are carried in specially designed baskets arranged under the hood into which controlled quantities of air or steam are introduced. A high speed fan ensures that every part of the charge receives adequate supplies of the non-scaling but decarburising atmosphere. Malleabilising cycles have been cut down to such an extent by this process that quite a small plant will give a considerable output when compared with a similar size of furnace using packing boxes and ore.

Tempering Furnace

The furnace illustrated in Fig. 13 is a recent installation by British Furnaces Ltd. for the tempering of laminated springs in the assembled state. The springs are conveyed through the furnace on three strands of chain as shown and at the discharge end pass under a water spray quench. The working chamber of the furnace is 7 ft. 3 in. wide by 46 ft. effective length and the operating temperature is 650° C. Heating is indirect by re-circulated hot air and products of combustion and three combustion chambers and re-circulation fans are provided. The fans are of large capacity to ensure uniform temperature and the fuel used is cold and clean producer gas. Full automatic temperature and safety control equipment is provided. This furnace was designed for an output of 2½ tons of springs per hour, but tests have shown that this output can be readily exceeded.

Miscellaneous Furnaces

There is a demand for small types of heat treatment furnaces suitable for laboratories, tool rooms and repair shops and two new designs have been produced by Kasenit Ltd. One is the bench type muffle furnace shown in Fig. 14, which is available in two sizes, viz., 9 in. long × 5 in. wide × 3 in. high and 12 in. × 8 in. × 5 in. and the other a double chambered bench type furnace (Fig. 15) for the heat treatment of high speed steel. Town's gas is used at a pressure of 2–3 in. w.g. In the former, temperatures up to 1,050° C. can be obtained, while in the high speed steel furnace, in which each chamber is 7½ in. long, 4½ in. wide and 4½ in. high, a temperature of 1,300° C. is obtainable in 20 mins.

Of considerable interest is a continuous furnace of the mesh belt type, designed and built by the General

Fig. 14.—A small bench-type muffle furnace.

Fig. 15.—A double-chambered bench-type furnace.

Electric Company, used for copper brazing at temperatures up to 1,130° C. and shown in Fig. 16. A controlled atmosphere is introduced into the furnace, which eliminates the necessity of a flux when brazing and, at the same time, ensures that the parts being brazed are clean and bright after treatment. The furnace can be used, of course, for bright normalising and other processes within its temperature limits. There is a range of sizes of these mesh belt furnaces, but the one illustrated is rated at 35 kw. and has a belt 8 in. wide. The leading vestibule is 6 in. high and the complete plant has an overall length of 37 ft.

It has only been possible to refer very briefly to a few typical installations, but it will be appreciated that many installations not less interesting have been omitted.

Fig. 16.—A continuous furnace of the mesh belt type for copper brazing at temperatures up to 1,130° C. It is suitable for bright normalising and other processes.

High Manganese Steel and its Deposition by Arc Welding

Continued from page 14

higher value than would be necessary with an ordinary mild steel electrode of the same size.

The salient feature of advocated welding procedures is that deposition should be carried out in weaved pads of not longer than 3 ins. in length for an 18 ins. electrode, the width of the bead being in proportion to the diameter of the electrode used, thus the Lincoln Handbook states that beads should be $\frac{1}{2}$–1 in. wide whilst Hadfields advocate a range of $\frac{5}{8}$ in. wide for 10 S.W.G. electrodes, $\frac{3}{4}$ in. for 8 S.W.G. and 1 in. for 6 S.W.G. Experience has shown, however, that the width of the bead should be approximately equal to twice the diameter of the electrode used. Long, narrow or shallow beads should be avoided.

Mechanical Characteristics

Except for hardness figures, data are lacking on the mechanical properties of austenitic manganese steel deposits, but Gregory[12] gives the following test results for 12% Mn steel with 1·1% C :—

Condition	M.S.	Elastic Limit	Elong.
Cast	36 tons/in²	20	30%
Rolled	62 "	29	35%
Forged	63 "	25	38%
Annealed	46 "	28	3%
Quenched 1,000° C.	55 "	—	40%

On Manganal (11–13% Mn, 2·5–3·5% Ni) the following results have been obtained :—

Max. Stress	..	140,000–150,000 p.s.i.
Elastic limit	..	55,000–60,000 p.s.i.
Elongation	..	72·5%
Red. in area	..	54%

Hadfields quote welding results shown in the accompanying table.

Conclusions

The foregoing summary of the characteristics of high manganese steel and its deposition by arc welding indicates clearly some of the problems entailed in the

BUTT-WELDED JOINTS.
Cold Bend Test (2 in. diam. former).

	Cast Parent Metal	Forged Parent Metal
$\frac{1}{4}$ in. × $\frac{1}{4}$ in. × 2 in. ..	50/90	150/190 (9 unbroken)

Tensile Test.

	Forged Parent Metal			
	M.S.	Elong.		
		$\frac{1}{2}$ in.	1 in.	2 in.
$\frac{3}{8}$ in. × $1\frac{1}{4}$ in.	40 tons/in.²	32%	24%	21%

ALL WELDED METAL
(As deposited).
Cold Bend Test ($1\frac{1}{4}$ in. diam. former).

$\frac{1}{2}$ in. × $\frac{3}{16}$ in.	90 unbroken

Tensile Test.

	M.S.	Elong.	
		1 in.	2 in.
0·445 in. × 0·475 in.	42 tons/in.²	18·75%	12/5%

perfection of an electrode and technique for the building up of work-hardening surfaces. The stimulus given to this aspect of reinforcing weak structures by the present shortage of Cr/Ni, and W alloys may well lead however, as indicated by the growing amount of technical data available, to a highly refined technique for the production of a work-hardening weld deposit capable of resisting the many diverse variations of treatment, heating, and abrasion applied by industrial usage.

Awards

The Council of the Institute of British Foundrymen has made the following awards for 1948.

The E. J. Fox Gold Medal to Mr. J. G. PEACE, M.Sc., in recognition of his services to the foundry industry.

The Oliver Stubbs Gold Medal to Mr. L. W. BOLTON, A.M.I., Mech.E., for outstanding services to the Institute, and as Secretary and later President of the Birmingham Branch.

The Meritorious Services Medal to Mr. C. LASHLY, M.C., for the high value of his services as Honorary Secretary of the Newcastle Branch for many years.

Staff Changes and Appointments

ARTHUR D. MERRIMAN, G.C., O.B.E., M.A., M.Ed.,, D.Sc. has been appointed Registrar-Secretary of the Institution of Metallurgists and took up full-time duties on 20th April, 1948. It will be remembered that hitherto Dr. Harold Moore, C.B.E., the Institution's first President, has served as Registrar, and that, under an agreement with the Iron and Steel Institute and the Institute of Metals, Mr. K. Headlam-Morley, Secretary of the former Institute, has acted also as Secretary of the Institution. By mutual agreement it was decided to bring this arrangement to an end and Dr. Merriman has been appointed by the Council to fill the dual positions of Registrar and Secretary. Dr. Moore has agreed to continue to make his experience available in a consultative capacity for six months.

Dr. Merriman's initial training was in physics, mathematics and chemistry, and after service in the 1914–18 war he had some 20 years' experience in academic fields, including the post of Principal of the County Technical School, Wallsend-on-Tyne, 1926–38. For nearly two years before the 1939–45 war he was Administrative Secretary to the Faculty of Architects and Surveyors, but was called to serve the Directorate of Scientific Research, Ministry of Supply, early in that war. He was the senior member of a group of scientists and engineers dealing with bomb disposal problems, and for his personal courage in emergency situations was awarded the George Cross. From 1941 to 1944 he was Scientific Adviser to the Commander-in-Chief, Middle East, and in 1944 was appointed to a special Intelligence assignment in Russia, followed by similar work in north-west Europe and Germany. He left the service in 1945 with the rank of Colonel, Royal Engineers, and since then has been Principal Scientific Officer (Technical Intelligence) at the Armaments Design Department, Ministry of Supply. He has had considerable experience as a lecturer and writer (is author of some 16 books on scientific subjects), and is a Companion of the Institution of Mechanical Engineers and a Fellow of the Corporation of Certified Secretaries.

Mr. F. G. BACON, B.Sc., A.M.I.Mech.E., A.M.I.E.E., Mr. H. C. BLENCH, M.C., and Mr. J. M. GRAHAM, have been elected to the Board of International Alloys, Ltd. Messrs. Bacon and Blench are, respectively, director of production and director of sales, while Mr. Graham is a director of Almin, Ltd.

Dr. A. H. LECKIE, Ph.D., F.R.I.C., succeeds Mr. R. H. MYERS, Assoc.Met., F.I.M., as head of the Steelmaking Division of the British Iron and Steel Research Association. Mr. Meyers has retired because of ill health.

Mr. H. LONGTHORPE has retired, after 35 years' service on the staff of The Churchill Machine Tool Co., Ltd., Broadheath, Nr. Manchester.

Mr. G. W. WATTS, Quinta Rosemarie, Avenida A. El Pinar, Caracas, Venezuela, has been appointed factory representative in that territory for Specialloid, Ltd.

Mr. E. S. WADDINGTON, M.S.E., M.Inst.W., A.M.I.E., Assoc.I.E.E., of the industrial department of Philips Electrical, Ltd., has been elected senior vice-president of the Society of Engineers Inc., for 1948.

Mr. A. E. SYLVESTER, F.C.A., and Col. H. C. SMITH, C.B.E., D.L., J.P., M.Inst.C.E., M.Inst.G.E., have accepted an invitation to become Chairman and Deputy Chairman respectively when the Gas Bill becomes an Act of Parliament. Mr. Sylvester was Chairman of British Gas Council from 1945–47, has been chairman of the South Eastern Gas Corporation, Ltd. since 1945, and a director of the Gas Light and Coke Co. since 1946. Col. Smith was President of the Institution of Gas Engineers in 1937–38, chairman of the British Council since 1947, and deputy chairman and managing director of Tottenham and District Gas Co. since 1946. He is also chairman of the London and Counties Coke Association, the National Federation of Gas Coke Associations and Solid Smokeless Fuels Association, and chairman of the Federation of Gas Employers and vice-chairman of the National Joint Industrial Council for the Gas Industry. With the approval of the Treasury the Minister of Fuel and Power proposes to fix a salary of £60C0 a year for the chairman and £5,000 for the deputy chairman.

Mr. H. S. PEISER, M.A., and Dr. W. F. FORD have recently joined the staff of Hadfields' Research Department. During the war, Mr. Peiser was engaged on work connected with atomic energy and the development of synthetic high polymers. Dr. Ford has written numerous scientific papers dealing with refractory materials.

Mr. W. H. SALMON, Assoc. Met., F.I.M., has been appointed the representative of Messrs. Hadfields, Ltd., in North West England and North Wales. He succeeds Mr. JAMES H. WHITTAM, M.I.M.E.E. During the last two years Mr. Salmon has been Messrs. Hadfields' technical representative for steel castings, and prior to that he was manager of their steel foundries for many years. From 1941–1946 he was a lecturer in foundry practice at Sheffield University; he was president of the Sheffield Branch of the Institute of British Foundrymen in 1945–46 and of the National Trades Technical Association, Foundry Section, for 1946–47.

Mr. W. H. BOWMAN, M.I.M.E., M.I.M., has been appointed technical director of the subsidiary companies, Reynolds Light Alloys, Ltd., Reynolds Rolling Mills, Ltd., and the South Wales Aluminium Company, Ltd., of the Light Alloy Division of Tube Investments, Ltd., and Mr. E. G. SNELUS has been appointed sales manager of Reynolds Light Alloys, Ltd., and Reynolds Rolling Mills, Ltd. He gained his early experience with Messrs. Davy and United Engineering Co., Ltd., the Brightside Foundry and Engineering Co., Ltd., and Henry Wiggin and Co., Ltd. Previous to joining Tube Investments in 1942, he was a specialist engineer with Leowy Engineering Co., Ltd., London. Mr. Snelus was sales manager of William Beardmore and Co., Ltd., until he resigned to join Tube Investments in 1945.

Mr. GEORGE ERNEST CHAPMAN has retired, after 52 years' service with Messrs. Hadfields, Ltd. Mr. Chapman joined the Company in November, 1895, as an office boy at the Hecla Works in Newhall Road. He proceeded through the commercial departments of the Company and for over 34 years supervised the sale of many of their specialities and safety appliances for mines. In 1946, on the completion of 50 years' service, he was presented by the Board of Directors with an ebony walking stick, as a token of their appreciation of his long and devoted service. He carries into his retirement the good wishes of the staff of Messrs. Hadfields.

British Industries Fair

Continued from page 26

plate is fitted and a separate chute, both of which can be cut away or removed to enable oversize and irregular dies to be fitted. Forged die links replace welded fabricated type. Ejector box has been re-designed so that the toggle pins are easily removed. Air cylinder piston is now fitted with woven fabric cup washers instead of piston rings.

This substantially new machine is claimed to be far superior in operation, production and maintenance than the old type machine.

Steel Tubes

Accles & Pollock, Ltd., on Stand D.619/518, exhibit tubes in steel, stainless steel and other metals ranging from the "smallest tube in the world," in stainless steel with an inside diameter of 0·0007 in., to internally polished, mirror finished tubes of 6 in. diameter. High precision tubes, diesel tubes, composite tubes, multi-bore tubes of small diameter and extreme accuracy, are shown. A range of hypodermic needle tubing and small diameter tubes in non-ferrous metals are included.

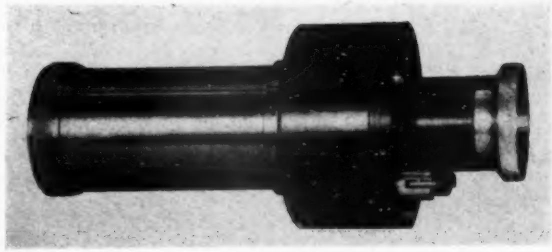
The interesting examples of tubular manipulation include Kromo S.A.Q. cycle tubes and components, tubular furniture bends, bus seat frames, and numerous other applications of tube manipulation for various industries. There is also a representative range of the well known "Apollo" tubular sporting goods—archery equipment, golf shafts, ski-stick shafts, javelins and fishing rods. A range of Apollo tubular box spanners and "Silentgrip" Spanner Sets are featured.

Welding Equipment and Accessories

Considerable developments have been made in the welding industry and a very wide range of electric arc welding plant, accessories and electrodes are exhibited. Some examples of these are shown by Murex Welding Processes, Ltd., on Stand 247–144. This firm has been fulfilling contracts for large numbers of diesel, petrol and electrically driven arc welding sets for leading oil companies and has accumulated valuable experience of the special requirements for this work. Special precautions have to be taken in the design of equipment for operating under arduous conditions and several welding sets are on view which are designed to meet exacting as well as arduous conditions.

Other equipment shown include a 250 amp. self-contained welding transformer fitted with the new Murex safety device. This overcomes the danger, under adverse conditions, associated with the changing of the electrode or the handling of the electrode holder, on an A.C. transformer type of equipment. The device is introduced into the secondary circuit of the transformer, i.e., between the output side of the self-contained transformer or choke and this electrode holder. The unit is a timed relay device which operates in such a manner that within a fraction of a second after the termination of a welding run the voltage at the electrode holder is automatically reduced from the normal 80 or 100 volts to approximately 30 volts.

Demonstrations are given with a new type SCC300 motor generator welding equipment and other types on view include the Murex light-weight petrol set, a static transformer arc welding equipment for one operator,



An Ether "Forgemaster" total radiator tube with a temperature range 700° C. to 2,000° C.

and a static transformer with oil immersed regulators, for three operators, and an entirely novel welding set the 175 amp. air-cooled transformer. A dual purpose screen and helmet is also shown together with a full range of welders' accessories.

Much progress has been effected in the provision of electrodes to provide a higher degree of reliability in the weld. Electrodes for welding mild steel, high tensile steels and heat resisting steels, non-ferrous metals, cast iron and electrodes for hard facing applications are exhibited by Murex in an illuminated and revolving cabinet. Demonstrations are given in the welding of ferrous and non-ferrous metals, including the recently developed type P.V. electrode, designed for welding deep groove type butt welds in thick mild steel. This electrode has been developed for the welding of pressure vessels to Lloyd's Class I and is also suitable for welding vacuum equipment and on work which is subsequently vitreous enamelled. Other new types of electrodes include "Firex," a plain extruded hydrogen controlled electrode for welding carbon and low alloy high tensile steels and to prevent hard zone cracking in the basis metal.

Some 18 welding machines are shown by Holden & Hunt, Ltd., on Stand C.719 and 618. One of the main features is a rivet heating and upsetting machine for assembling the crown wheel to the differential casing of the Ferguson tractor, which is a working exhibit. Another noteworthy machine is the 15/30 kVA light alloy foot-operated spot welder with an electronic timer, which is capable of welding aluminium, brass and other non-ferrous alloys. A chain welder is also at work welding short link chain. Included also are 15 kVA and 25 kVA spot welders of the rocker arm and sliding head types respectively; three sizes of auto butt wire welders covering a range of ferrous and non-ferrous wires from 22 swg. to ½ in. diameter; a motor driven spot welder with infinitely variable A.C. motor.

New Process Welders, Ltd., on Stand C.118, show a fully automatic pram or cycle wheel rim butt welder with motor drive and air-operated clamping; a spot welding machine of very ususual design, including two transformers and making two welds simultaneously; a pedal-operated spot welding machine which is air-assisted; an air-operated spot welder of unusual design, built on the lines of a radial drill; two standard pedal-operated spot welding machines; a small 2 K.V.A. laboratory type spot welding machine with alternative fixtures, bench attachment and hand pliers.

Three types of electric resistance welders shown by British Insulated Callender's Cables, Ltd., the well-known pedal operated spot welder No. 94, a general purpose machine with a 20 kVA rating for welding mild

steel up to $\frac{3}{8}$ in. added thickness or aluminium up to $\frac{1}{16}$ in. added thickness. A continuous spot welder and a bench-type butt welder, No. 109, are also shown. A small part of the display is devoted to high frequency equipment where the latest models of high frequency heaters, welders and soldering machines are shown.

Heat Treatment Equipment

Developments in heat treatment equipment are referred to elsewhere in this issue where installations are briefly described which are too large to exhibit at the Fair. The practice of showing large photographs of recent installations is again adopted and furnaces for every heat treatment process is represented among the photographs exhibited by G. W. B. Electric Furnaces, Ltd., on Stand C.321-220, including mesh belt conveyors, pushers, chain conveyors, bell type furnaces, billet heaters and many others. A standard town's gas plant for producing protective atmosphere for bright annealing, brazing, etc., and samples of Eternite case-hardening compound, Shell-Wild-Barfield quenching oil and other hardening shop requisites are shown. Working exhibits include a 70 kW " Autolec " electrode boiler capable of raising 230 pounds of steam per hour, and demonstrations will be given of the rapid manner in which steam can be produced with this type of equipment.

Wild-Barfield Electric Furnace, Ltd., on the same stand, show a range of equipment extending from small laboratory muffles to full scale production furnaces, including forced air circulation equipments. Laboratory muffles include tube and horizontal rectangular types, the former being available with tube lengths of 12 in. or 20 in. with a 2 in. diameter. Temperature regulation is by means of built-in energy regulators, requisite pilot lights being incorporated. These tube muffles are suitable for temperatures up to 1050° C. The horizontal rectangular muffles have chamber sizes ranging from 8 in. × 3 in. × 3 in. to 19 in. × 7½ in. × 5 in. Smaller models are completely self-contained and have built-in temperature controllers and pilot lights. All sizes are fitted with a door switch, flue with damper, protective atmosphere entry and thermocouple entry.

Three equipments are shown to cover the toolroom and small production side. These are the toolroom tempering furnace, the horizontal " Workshop " furnace and the " ESB Minor " electrode salt bath. Full scale production furnaces will be represented by a standard horizontal " Heavy Hairpin " batch type furnace fitted with a Paragen burner. Most equipments are shown in operation. They are supplemented by exhibits of gas carburised work. Induction hardened, brazed and soldered samples treated by Ferranti-Wilk-Barfield equipment are also shown, and dielectric processes are covered.

Electric Furnace Co., Ltd., together with their subsidiary companies, Electric Resistance Furnace Co., Ltd., and Electro-Chemical Engineering, Ltd., are exhibiting on Stand C.611. The latest adaptations of high frequency induction heating for forging, brazing and soldering, and heat treatment, are emphasised. This process is ideal for mass production and shows a large saving of time and cost over carburising. Typical samples of parts treated are shown. As an illustration, many thousands of swivel pins for the caterpillar tank tracks were treated during the war. This application has now been turned to peace time use in the manufacture of tractors for home and export use.

A new development of this company is the Efco-Karboclean process for reconditioning motor car engines. This process will perform the combined operation of degreasing and carbon removal more efficiently and at a fraction of the cost of other methods. A small cleaning unit is exhibited enabling visitors to see samples of work treated on the spot.

Another feature of the Efco Stand is a fully automatic Efco-Udylite plating machine which demonstrates the method of transfer of a typical return type machine. The plating racks on which the work for processing is held are loaded and unloaded adjacently. The overall dimensions are 20 ft. long × 10 ft. high × 4 ft. 2 in. wide (excluding fume exhaust equipment). The size of rack for the machine shown is 12 in. × 21 in.; the transfer speed being 25 ft. per minute. The machine has six process tanks and will handle up to 75 racks per hour, depending on the time cycle selected. Efco-Udylite plating machines are built in three standard sizes—for cyanide plating, bright nickel, and bright nickel and chromium plating respectively. Non-standard machines are also built to suit special requirements. Samples of steel, aluminium and zinc base articles plated with Udylite bright nickel will also be shown.

Birlec, Ltd., confine their exhibits to special model and photographic displays of the more interesting and latest phases of electric furnace design—gaseous malleable annealing, steel melting (direct and indirect arc), induction heating and melting, pottery firing, gas carburising and copper brazing.

The Birlec gaseous annealing process for whiteheart malleable castings makes it possible to eliminate entirely both cans and iron ore and to reduce the annealing cycle to a matter of 48 hours or so instead of 5 days or more as in the case of the conventional process. A scale working model of the Birlec elevator furnace will demonstrate the characteristics of the furnace and will be supported by installation photographs.

The modern process of gas carburising is cleaner, quicker and more economical in fuel, labour and materials than pack carburising, and furthermore, it permits that degree of precise control over the operation which is demanded by modern heat treatment specifications and which is difficult or impossible to achieve by the older method. In gas carburising, as in other heating and heat treatment spheres, Birlec has pioneered the development of equipment on a sound, practical basis, and all types of equipment are available for every carburising application—batch and continuous, electric or fuel-fired. A photographic display is arranged in conjunction with typical carburised components.

A standard Birlec continuous belt conveyor controlled atmosphere furnace for bright annealing and brazing is shown in operation. This unit, which is equipped with atmosphere generator, is used in many industries for bright annealing, pressings and other small parts, and for the bright copper brazing of small steel assemblies.

Examples of Birlec high frequency induction heating equipment are also shown demonstrating particularly the highly-developed mechanical devices built for the automatic feeding of the material and timing of the process. The induction heating exhibits will be centred round a small working model of the rotary type con-

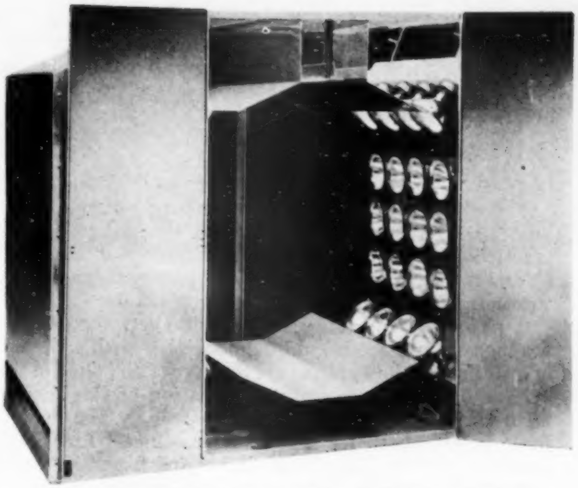
tinuous billet heating machine which Birlec is building for large production requirements.

METALECTRIC FURNACES, LTD., an associated company of The Incandescent Heat Co., Ltd., show a typical "Thermonic" induction generator with a work table providing maximum flexibility and utilisation. In this set high frequency energy is produced by means of a vacuum valve oscillator. The equipment converts ordinary power line frequency to frequencies of the order of 375,000 cycles per second. A plate transformer raises the voltage to approximately 10,000 volts. A rectifier then converts this current to full wave direct current at an average value of 9,000 volts. Choke coils and by-pass condensers prevent feed-back into the power source. The oscillator section consists of water-cooled 3-electrode vacuum valves, a tank circuit made up of a tank condenser and a tank coil inductance, and a coil for feeding back high frequency energy to the grids of the 3-electrode vacuum valve. The current from the power supply section is applied across the plate and filament of the oscillator valves, in which the flow of current is controlled by the action of the grid. The oscillator valves feed high frequency energy through a blocking condenser, which permits only the passage of high frequency current to the tank condenser and tank inductance. The tank circuit has a natural resonant frequency of approximately 375,000 cycles per second. When this circuit receives a direct current impulse, its natural tendency is to oscillate at its basic frequency, causing alternating current to flow in its component parts. The current produced in the tank coil is picked up by a coupling unit, and a small portion of the available energy returned to the oscillator valves. This grid energy causes the valves to "block" and "fire" in synchronism with the resonant tank circuit. Impulses are thus fed to the tank circuit at exactly the right moment, so that the oscillations are continuous. The circulation of this high frequency current makes available energy for use in various applications.

This form of heating is now being applied with great success to such operations as surface hardening, brazing, annealing, internal hardening of cylinder bores, soldering, melting and sintering. Many of these operations are easily adaptable to continuous working, giving highly efficient and economic production.

REDIFFUSION, LTD., have recently designed three new radio heaters specially for the heat treatment of metal components by induction heating. The new Redifon IH. 38 is the first of these and the two following models are the 30 kW. Redifon IH. 5 and the 6 kW. Redifon IH. 39. Elsewhere in this issue it will be noted that this firm recently supplied an induction heater to Wyvern Pens. This machine is used to anneal the gold nib blanks prior to rolling into the semi-circular shape.

The General Chemicals Division of IMPERIAL CHEMICAL INDUSTRIES, LTD., on STAND D.315-212, concentrate on "Cassel" heat treatment and on metal degreasing. Exhibits will include "Cassel" salt bath furnaces for the heat-treatment of steel, and an automatic austempering furnace. Designed by the I.C.I. Metals Division for use in their own works, these furnaces eliminate the human element, thus saving time and man-power and ensuring complete uniformity of treatment. Standard and special models of I.C.I. Metal Degreasing Plants were also shown. They include two mechanised plants —an automatic vapour-liquor plant and a continuous rumbling liquor-vapour plant.



The New B.T.H. Mazda Infra-Red Lamp Oven

Heat Control and Measuring Instruments

ETHER, LTD., this year feature a comprehensive range of heat control and measuring equipment in the form of electronically operated recorders, controllers and combustion safeguards. Their "Wide-Strip" electronically operated potentiometer is exhibited for the first time. This instrument represents the latest advance in recording potentiometer design, the electronic circuit employs a unique reactor unit for converting the D.C. out of the balance currents into A.C., thus enabling a valve amplifier to operate a special 2-phase motor which drives the balancing mechanism. The instrument has a chart 10 in. wide and the record is formed by a direct writing ink pen; the operation is extremely rapid, the pen covering the chart width in 28 seconds, but instruments having higher or lower deflecting speeds can be made to special order. This instrument is made to control, in addition to indicating and recording providing on-off—high-low, multi position and proportional control.

This firm also show electronically operated Ether-Wheelco "Capacitrols" and Ether-Wheelco "Flame-otrols." Both of these instruments are electronically operated. The Ether-Wheelco "Capacitrol" is a direct deflection indicating controller and has many advantages over the old chopper bar type since the control action is instantaneous and involves no running motors or mechanical parts. The control action operates between very fine limits and the instrument moving system remains free from trouble for long periods since no wear of its pivots or jewels takes place due to "Chopping" of the pointer. Temperatures between $-200°$ C. to 2,000° C. can be indicated and controlled. The Ether-Wheelco "Flame-otrol" is an electronic device which is designed to prevent explosions in gas, oil and pulverised coal fired furnaces and provides a complete combustion safeguard against explosions.

The Ether "Forgemaster" total radiation pyrometer, which enables the measurement of temperatures up to 2,000° C. The unit is focused on to the interior of the furnace from the outside of the furnace so that no deterioration takes place due to the contact with these high temperatures. A unit is exhibited, as also is a new model of this firm's "Indicorder" continuous chart recording and controlling pyrometer, type L.C.R.

This instrument is of the chopper bar direct deflectional type with a chart width of 5 in. and a chart speed variable between ½ in. to 6 in. per hour. Thermo-couples, radiation tubes and resistance bulbs are used in conjunction with this instrument over a temperature range of $-200°$ C. to $+2,000°$ C. and a full range of electrically operated valves are available to enable the instrument to control gas, oil and other types of furnaces.

The high frequency induction melting furnace is well known and accepted by all quality steel makers. It is not practicable to exhibit a working furnace but ELECTRIC FURNACE CO., LTD., show a high frequency furnace body together with illustrations of working plants.

A scale model of the BIRLEC MNT Lectromelt direct-arc melting furnace is exhibited together with a display of installation photographs of other types and sizes of this same design. The foremost application of this furnace is in the manufacture of electric steel by the acid or basic process both for ingots and castings. Practically every type of steel can be made ranging from high-grade refined alloy steels, tool steels and stainless steels to the commercial types of rimming steel which compete with the basic open hearth product. Its application in the iron foundry is a growing one and in small units it is being widely used for the production of high duty iron. It is also invaluable for high sillimanite materials, high chromium alloys and austenitic cast irons. A new style small model N indirect arc furnace is exhibited, a unit designed for laboratory development and small scale production work having a charging capacity of 10 lb.

The application of high frequency heating to melting processes is finding increased popularity for melting carbon and alloy steels, cast iron, copper, brass, bronze, nickel, nickel-alloys and precious metals and by reason of their close collaboration with the Ajax Electrothermic Corporation of America, and their own extensive experience of melting problems, BIRLEC are able to offer standard equipment with all the technical, practical and economical benefits of induction melting for both ferrous and non-ferrous melting. For melting aluminium and light alloys, the Birlec-Tama furnace is already well known and a special model is exhibited supported by representative photographs for both high frequency and low frequency melting equipment.

The furnace department of THE MORGAN CRUCIBLE CO., LTD., designs and constructs many types of crucible furnaces, all of which are designed to show the highest metal melting efficiency coupled with the strictest economy in fuel consumption, being rapid melters consistently with long crucible life; they are designed to the last detail for easy and comfortable operation; they are economical of labour and of floor space, and they are all versatile in the metals and jobs for which they can be used. They include the lift-out crucible type; the bale-out crucible; central axis tilting furnace; the Morgan hydraulic tilting crucible furnace; multiple furnace with one hydraulic unit and remote control; the Morgan rotary furnace for melting swarf, turnings and powders. Examples of these furnaces are on view, with the exception of the multiple furnaces; in this case, however, an action photograph shows a battery of furnaces operated by one hydraulic unit.

Carbon Engineering Parts

Of great interest is the variety of Morganite carbon engineering parts which vividly illustrate the versatility of this modern engineering material. The number and variety of industries served by carbon is a revelation to engineers, particularly when it is realised that not one of the specialised applications for which the parts are used could have been served so well by any other material. Electrical brushes, crane current collectors, trolley bus inserts, pantograph strips for overhead current collection, telephone electrodes, and welding carbons, all illustrate the normal electrical properties of carbon. Carbon pile resistors and telephone granules and shot, illustrate an unusual electrical property of carbon, namely the pressure sensitive contact resistance of the material.

Among the many heat applications of Morganite carbon are furnace tubes, boats, and moulds, which are used in an inert atmosphere for carburising metal alloys at temperatures in the order of 2,000° C. Carbon has the property of not being wetted by molten metal or glass, which is invaluable in both the metallurgical and glass industries. This property ensures that neither molten metal nor glass adheres to carbon, and consequently cannot be contaminated by it. It is utilised in moulds for the casting of special steel alloy ingots, in Carblox corrugated blocks for blast furnace hearths, and in the glass industry, in dies, moulds, and formers.

It is a highly instructive experience to see this range of widely different carbon products grouped together and observe the high degree of precision to which carbon can be machined or moulded, and it frequently suggests a solution to an engineering problem, either by adaptation of an existing Morganite carbon product, or by the development of a new product to take advantage of the unusual properties recommending carbon to wider fields of industry.

International Conference of Surface Reactions

THE Pittsburgh International Conference on Surface Reactions will be held at the Mellon Institute for Industrial Research in Pittsburgh, June 7th to 11th, 1948. The Conference Committee is made up of the following: Dr. Earl Gulbransen (Westinghouse Research Laboratories), Chairman, representing The Electrochemical Society, Pittsburgh Section; Prof. D. S. McKinney (Carnegie Institute of Technology) representing The University Conference on Corrosion and Metal Protection; Prof. Mars Fontana (Ohio State University), representing The Electrochemical Society, Corrosion Division; J. M. Bialosky (Research Laboratory, Carnegie-Illinois Steel Company), representing The National Association of Corrosion Engineers; Dr. J. W Hickman (Westinghouse Research Laboratories), representing The Pittsburgh Physical Society; C. Pogocar (Mellon Institute for Industrial Research), representing The American Society for Metals, Pittsburgh Chapter; Dr. George H. Young (Mellon Institute for Industrial Research), representing The American Chemical Society, Pittsburgh Section; Richard Rimbach (Corrosion Publishing Company), representing The Corrosion Forum.

Preliminary plans call for technical sessions mornings and evenings and visits to Pittsburgh research laboratories, which are working on surface reactions, in the afternoons. Scientists, engineers and educators from many parts of the world have been invited to participate in the Conference and several will present papers.

It is interesting to learn, in a recent note from America, that there has been a survey made concerning the necessity for standardising microchemical methods. Seventeen university laboratories and fifty-six industrial laboratories gave their views. Of these, sixty-four agreed that standardisation was necessary, while forty-six expressed themselves willing to collaborate in the standardisation. As a result, it is proposed to commence with the standardisation of the determinations of carbon, hydrogen and nitrogen. It has long been our view that some body in this country should undertake similar work. Routine microchemical methods such as those mentioned lend themselves particularly to standardisation. Indeed, any worker familiar with the determinations knows that his own methods must be rigidly standardised or his results will be of little value. From this admission, it is but a step to the realisation that there is no valid reason why different workers should not follow the same standard practice. Admittedly such standardisation will not come about by wishing for it. It will mean work, much work and hard work, by many volunteers, followed by co-ordination in a central organisation. Here, it seems to us, is work to be initiated by the Microchemistry Group; work, in fact, which the Group should regard as part of its duty. Or, since to call it a duty might suggest something a shade distasteful, perhaps we might call it work which the Group should regard as part of its rightful function in the chemical circles of this country.

Improved Gravimetric Determination of Silicon in Aluminium Alloys, developed in Germany during the War

By W. Stross

The method described in this paper, which is based on the mutual flocculation of gelatine and silicic acid, was tested and found to be a definite improvement on existing gravimetric procedures. A minor modification is recommended.

THE usual methods for the gravimetric determination of silicon in aluminium alloys are based on the precipitation (dehydration) of silicic acid by "fuming" or baking with strong acid. In general, the alloy is attacked in a nickel vessel, with caustic soda (sodium peroxide or hydrogen peroxide being added, if necessary), thus converting the silicon to sodium silicate. The solution is then acidified and the silicic acid thus obtained is dehydrated. The classical Regelsberger procedure[1] uses sulphuric acid, more modern methods [2a–c] perchloric acid. In either case it is necessary to boil down to fumes of the acid and to fume or bake it for some time in order to render insoluble at least the major part of the silicic acid in a filterable form. During this stage there is, particularly with the Regelsberger procedure, some risk of loss by "spitting" and of the formation of insoluble, or at least not easily soluble, salts, necessitating thorough boiling after dilution. Even so, it may still be necessary to resort to differential weighing before and after treatment with hydrofluoric acid, in order to obtain the true silica figure.

It is well known that in the Regelsberger method a substantial part of the silicic acid remains unprecipitated after the first dehydration, and that it is necessary to recover this fraction, even for work of moderate accuracy, by taking down the filtrate to fumes and fuming a second time. This second dehydration and filtration and the HF treatment obviously considerably increase the time required. For the perchloric acid, it is claimed that substantially quantitative precipitation is obtained with the first fuming; this does not, however, seem to be a general experience (2b, p. 20, 2c, and personal communications from various analysts).

In the more recent Fuchshuber method,[3] the conversion of the silicon is achieved by a special acid attack, and this method, slightly modified,[4] has been found in our laboratories to be time saving and reliable if practised by experienced and careful operators; it has, however, the disadvantage that it is not applicable to alloys with less than about 3–5% silicon. A similar restriction of the range applies to recent attempts[5a, b]

1 See, for instance, Chemical Analysis of Aluminium and its Alloys, The British Aluminium Company, publication No. 405, 1947, p. 122.
2a Willard, H. H., and Cake, W. E., *J. Am. Chem. Soc.*, **42**, 1920, 2208.
2b Perchloric Acid, published by the G. Frederick Smith Chemical Company, Columbus, Ohio, 1940, p. 18ff.
2c A.S.T.M. Methods of Chemical Analysis of Metals, American Society for Testing Materials, edition 1946, p. 145.

3 *Z. Anal. Chem.*, **116**, 1939, 421; **123**, 1943, 9; **125**, 1943, 93.
4 Osborn, G. H., and Clark, J., *Metallurgia*, **31**, 1945, 230.
5a Lisan, P., and Katz, K. L., *Anal. Chemistry*, April, 1947, 252.
5b Norwitz, G., ibid., **20**, 1948, 182.

at combining the Fuchshuber and the perchloric acid methods.

In view of the above, the writer was interested in a modified and improved Regelsberger procedure developed during the war in the Materialpruefungsanstalt (Institute for Testing Materials) in Berlin. *Professor H. Blumenthal*, of this Institute, readily communicated full particulars of their unpublished procedure, when interviewed, in summer, 1946, by a B.I.O.S. team of investigators, of which the writer was a member.[6]

Experiments in this laboratory confirmed Blumenthal's statement that the method is a considerable improvement on existing gravimetric procedure and, in view of the importance of the subject, it was thought that chemists in this country might be interested in a report of our experience and procedure, although it contains —apart from a minor modification—little original work.

Principle of the Method

The procedure is based on the work of L. Weiss and H. Sieger[7] on the mutual flocculation of gelatine and silicic acid and other colloids. The attack follows the lines of the Regelsberger procedure. After acidifying and dissolving any undissolved metallics by the addition of hydrogen peroxide, the solution is boiled down only slightly (i.e., *not* to fumes) and gelatine is added. This rapidly leads to quantitative flocculation of the silicic acid in a very pure and easily filterable form. The precipitate is filtered off, washed, ignited and weighed, no recovery of silica from the filtrate and no treatment with hydrofluoric acid being necessary.

The method is equally well applicable to alloys of all ranges from 0·1–40% silicon.

Reagents Required

Sodium hydroxide, pellets or sticks, AR grade.
Sulphuric acid, diluted 1 : 1 (v/v).
Hydrochloric acid, diluted 1 : 1 and 1 : 9 (v/v).
Hydrogen peroxide, 20 vols.

Gelatine solution, 0·25%.—Dissolve the gelatine freshly, in warm water (without boiling) and use, or prepare in bulk, in this case, keep sterile by adding a few pea-size crystals of thymol to the rapidly cooled solution (if thymol is added to the hot solution, turpidity tends to develop and the solution may not function properly). Shake thoroughly several times during the first hours after adding the thymol so that a concentration of thymol sufficient to prevent microbial growth rapidly throughout the whole solution.

Sodium hydroxide solution: 300 ml. of water are added to 100 g. of the solid.

Sodium peroxide.

Procedure

Take a 2 g. sample for alloys with less than 5% of silicon, 1 g. for 5–10% Si, 0·5 g. for 10–40%. (The limits of these ranges are not critical.)

Place the samples in suitably sized nickel vessels or, advantageously, in 350 ml. stainless steel beakers.

Add 5 g. of caustic soda to 0·5 g. samples, 6–7 g. to larger samples. Add 10 ml. of water and cover with nickel lid.[8] When the violent reaction is over, cautiously add 50 ml. of water and boil gently. The maximum time required for complete conversion of the silicon is about 30 minutes.

On alloys with more than 20% silicon, complete conversion of the silicon is more easily obtained by treating them with 15 ml. of the sodium hydroxide solution, then cautiously adding 5 g. of sodium peroxide, followed by another 30 ml. of water and boiling, as before.

Transfer the solution into a beaker containing a suitable quantity of diluted acid. Use hydrochloric acid for samples containing more than 1–2% of tin or lead, for all other samples, however, sulphuric acid is preferable because all fumes are avoided in the subsequent stages. If hydrochloric is used, take 120 ml. of the 1 : 1 dilution for a 2 g., 100 for 1 g., or 60 for 0·5 g. samples. If sulphuric acid is used, take 60 ml. of the 1 : 1 dilution for a 2 g. sample, 30 ml. for a 1 or a 0·5 g. sample. Rinse the metal vessel with small portions of warm hydrochloric acid 1 : 9. Copper and other undissolved metals are dissolved by adding, in portions, 10–15 ml. of hydrogen peroxide. Boil until the volume is approximately 50 ml.* for a 2 g. sample, 40 ml.* for a smaller sample, when in general it will be seen that flocculation of the silicic acid has begun.

Cool to about 60° C., add 40 ml. of the gelatine solution, and some water (20 ml. of water to a 2 g. sample, 10 ml. to a smaller sample). Stir† vigorously to form froth and to stir in air, which helps in precipitating the silicic acid. Allow to stand for at least 10 minutes, then filter through a medium texture filter paper (e.g., Whatman No. 40, 12·5 cm. dia.). Use a "Cobby" to ensure complete transfer of the precipitate. The filtration is rapid and the filtrate nearly always clear; in rare cases only is it necessary to pour the first portion of the filtrate back on to the filter.

Wash well—six to eight times is usually sufficient—with hot water containing approximately 20 ml. of the gelatine solution and 10 ml. of the dilute hydrochloric acid 1 : 1 per litre. Wash until the filtrate is free from sulphate, when tested with barium chloride solution.

Cautiously ignite the moist filter, finally at least to 950° C., and weigh.

The time required is about 2 hours.

Discussion

It seems fairly obvious that this method is simpler and shorter than other procedures as substantial parts of these are entirely eliminated here; it should also be emphasised that it was found very easy to train operators for the gelatine method, and that the operators preferred the gelatine to other procedures, not only because of its speed but also because it requires less attention and labour. This method is, therefore, very suitable for routine application, unless the still more rapid photometric procedure is used.

The accuracy and reproducibility (precision) obtained in routine application are illustrated by the Table I, in which *all* the results obtained in this series have been reported.

The figures given for the gelatine method all refer to the procedure described—i.e., one precipitation only and no hydrofluoric acid treatment of the ignited precipitate. Hydrofluoric acid was used as a check in a number of cases, but the residue was within the weighing error.

Blumenthal prescribes 10 ml. of 1% gelatine solution and favours the preparation of a fresh solution each

6 This information was published as B.I.O.S. Final Report No. 2580, reported by W. Stross, H.M. Stationery Office, London, 1947. Since this paper went to press the writ r found that the book "Leichtmetallanalyse" by H. Ginsberg, 2nd ed. (printed as MS., in restricted numbers, at Oslo, 1945, under license of the publishers de Gruyter und Co., Berlin) contains, on p. 48, a full account of this procedure. The writer cannot assess whether this book was Blumenthal's source or vice versa.

7 *Z. Anal. Chem.*, **119**, 1940, 245.

8 Nickel lids in suitable sizes suitable for the stainless steel beakers are more easily obtainable commercially than stainless steel lids.

* It is advantageous to mark these volumes on the vessels used.

† If 650 ml. Phillips' beakers (which we find very advantageous) are used, it is sufficient to swirl the solution vigorously, i.e., no stirring is required.

TABLE I—IMPROVED GRAVIMETRIC DETERMINATION OF SILICON.

Alloy Type	Sample	By proposed Method % Silicon	Comparison Results %
D.T.D. 324 ..	Intal Standard	11·34, 11·36, 11·43, 11·47.	11·4*
D.T.D. 324 ..	Alar „	11·31, 11·37, 11·42	11·30* (11·25–11·37) 11·34‡, 11·38‡
D.T.D. 424 ..	Alar „	4·91, 4·93	4·89* (4·83–4·95)
Piston Alloy	Intal „	6·20, 6·26	6·18*
D.T.D. 428 ..	Alar „	2·71, 2·71, 2·73, 2·73, 2·76, 2·78	2·70* (2·63–2·78)
D.T.D. 133c	Alar „	2·49	2·43* (2·38–2·50)
RR. 50 ..	No. 697L	2·66	2·65*
RR. 56 ..	Intal, N—Standard	1·10, 1·09	1·06*
Duralumin ..	Intal, "D"	0·49, 0·49	0·48*
Synthetic Samples ..	Mixtures of Duralumin and super pure aluminium	0·25, 0·24	0·24 calculated
		0·13, 0·14	0·12 „
D.T.D. 424 ..	Production sample	5·20	5·17‡, 5·18†
Si-hardener..	TFS 1 B	20·08, 20·05	
„ „	TFS 2 B	20·02, 20·01	
„ „	TFS 3 B	19·62, 19·64	
„ „	TFS 4 B	20·08, 20·15	
„ „	TFS 5 B	20·07, 20·05	
„ „	Number lost	19·21, 19·16	

* Average of a considerable number of determinations, done (mostly in several laboratories) by a number of different methods; the numbers in brackets give the extreme deviations.

† Comparison figure obtained by the photometric procedure.

‡ Comparison figure obtained by the modified Fuchshuber procedure.

time; as an alternative he recommends stabilising the 1% solution by adding toluene.

Weiss and Sieger mention the addition of 0·02% of the benzyl ester of p-oxybenzoic acid for preserving the gelatine but prefer using a freshly prepared 2–5% warm solution.

We found that the 1% solution tends to set to a jelly unless the room temperature is very high and that the use of toluene was unsatisfactory. The 0·25% solution[9] stabilised by thymol develops less froth than the freshly prepared solution, but works perfectly satisfactorily and keeps very well, without setting. As far as the writer could ascertain a Russian author[10a] was the first to propose the use of gelatine for the determination of silicic acid. His work as well as that of two other Russian[10b] and of a Dutch[10c] and of two other[13a, b] authors, was, however, concerned with the analysis of clay and similar materials, not of aluminium alloys.

The Dutch[10c] author emphasises that under his conditions—i.e., in hydrochloric acid medium—a small quantity of silicic acid remains unprecipitated even after the addition of gelatine, although the proportion is very much smaller than without the use of gelatine.

Gelatine has also been used by various other authors in the analysis of aluminium alloys for silicon.[10d-f, 11]. These papers, however, deal only with alloys of the "Silumin" type (containing more than 10% of silicon), and in the first two papers the gelatine is used more as an aid to the filtration of the silicic acid already precipitated than as a precipitant. The last remark also applies to a more recent method where the addition of gelatine is recommended *after* the silicic acid has been fumed with sulphuric and perchloric acids "to facilitate the filtration of the silica."

The writer feels that it is also a definite advantage of the Weiss-Blumenthal method that no perchloric acid is used; although this acid, at the present standard of purity, is much less dangerous than appeared some time ago, it is still not a harmless material, particularly if used in routine on a large scale and over a considerable time, quite apart from considerations of cost.

Weiss and Sieger remark that approximately 0·1 g. of gelatine is required for the complete precipitation of 1 g. of silica, but that even a considerable excess does no harm, although it may produce turbidity of the filtrate which, however, disappears on warming. These authors also point out that gelatine can also be used advantageously in the precipitation of titanium, tantalum, niobium, calcium fluoride and of the sulphides of zinc[12] and trivalent arsenic.

The experiments carried out in this country were done in the laboratories of Messrs. International Alloys, Ltd., Aylesbury, the investigations in Germany were carried out for the Ministry of Supply. Thanks are due to the B.I.O.S. Group II (Metallurgy) of the Ministry, and to the Directors of this Company, for the permission to publish. The writer also wishes to thank the members of the laboratory staff, Mr. J. Clark particularly, but also Mr. McMaster and Miss Neill, for carrying out the analysis.

9 Stross, W., *Metallurgia*, **36**, 1947, 163, 223.
10a Timofejeff, K. N., *Zavod. Lab.*, 1933, 13.
10b Tananaeff, N. A., and Buitschkoff, M. K., *Z. Anal. Chemie*, **103**, 1935, 349.
10c Spronck, S. J. H., *Chem. Weekblad*, 43, 0947, 259; contains also references to older literature—*e.g.*, R. Zsigmondy, *Kolloidchemie*, 1928, 212.
10d Vasilev, K. A., and Getsova, S. Y. A., *Zavovod. Lab.*, **9**, 1940, 1,087 (Chem. Abstr. **34**, 1,347).
10e Nikolaev, N. S., *ibid*, **10**, 536 (Chem. Abstr. **38**, 2,285).
10f Geigenmüller, M., *Aluminium*, **24**, 1942, 178.
11 It might be mentioned here that the precipitation of silicic acid by gelatine (in the form of glue) has also found industrial large scale application in Germany for the preparation of beryllium salts from beryl (B.I.O.S. Final Report No. 945, reported by W. Stross, H.M. Stationery Office, London).
12 Gelatine has been used for this purpose by Caldwell and Moyer, *J. Am. Chem. Soc.*, **57**, 1935, 2372.
13a Hammarberg, E., *Jernkontorets Ann.*, **131**, 1947, 199 (*Chem. Abst.*, 1947, 6489) deals with the determination of Si in pig-iron, steel, ferro alloys and silicates, with the use of gelatine.
13b Huegi, Schweiz, *Mineral. u. petrogr. Mitt.*, **25**, 1946, 534 (*Chem. Abstr.*, 1947, 2,659) with the determination in silicates. These two papers were not accessible to the writer in the original.

Some Apparatus for Micro-Titration

By P. F. Holt and D. G. Stringer

APPARATUS used in micro-titration was comprehensively reviewed by Wyatt.[1] Of the pipettes described, many are not generally applicable, having been designed for some special type of titration, whilst some require tedious manipulation or give considerable delivery error. A very simple type of pipette used regularly in this laboratory for several years has been proved rapid and simple in operation, widely applicable and consistent and accurate in delivery.

The pipette was designed with the following considerations in mind: (1) The internal surface area should be as small as possible to minimise drainage errors, thus the bore of the tubing is made wide and the length short. (2) In measuring small volumes it is difficult to bring a meniscus exactly to a measuring mark, particularly when the diameter of the tube is small. The measuring mark is, therefore, dispensed with and, instead, the pipette is filled to the tip of a capillary. (3) Mouth suction is undesirable since traces of organic material inevitably find their way into the pipette and cause irregular drainage. The pipette is filled by means of a rubber teat. (4) Manipulation should be simple and rapid so allowing little time for reactive solutions to

1 Wyatt, G. H., *Analyst*, **69** (1944), 81.

be affected by the atmosphere. (5) The design should be applicable over a wide range of volumes from about 1 ml. downwards.

The pipettes are made from glass tubing of 5 mm. or smaller, bore which is drawn out to capillary bore at either end, the capillaries being cut cleanly a few milli-

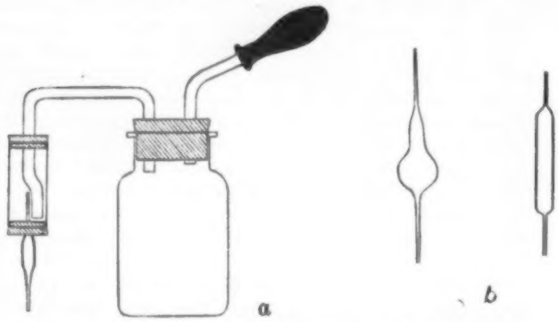


Fig. 1.—Some pipettes and a suitable clamp.

metres from the thicker tubing. Larger capacity pipettes are made of the same length but the tubing is blown into a bulb before the capillaries are formed. Both types are illustrated in Fig. 1b.

The pipettes are held in the clamp and suction apparatus illustrated in Fig. 1a, which consists of a short length of glass tubing of about 4 cm. in length and 15 mm. diameter closed at both ends by one-hole rubber bungs, the lower of which holds the pipette. The upper bung carries a glass tube which reaches to within 1 mm. of the lower bung and is connected through two right-angle bends to a two-hole rubber bung inserted into the mouth of a small bottle.

The second hole of the bung carries a glass tube closed at its outer end by a rubber teat which has a straight cut in the wall 2–3 mm. long. According to the manner in which the teat is held, the slit can be kept closed so that air may be forced out of the apparatus or may be opened to equilibrate the inside pressure with that of the atmosphere.

The pipette is filled when the teat is compressed, then released with the tip beneath the surface of the liquid Excess liquid flows from the pipette into the outer tube and, when the pipette is next filled, is sucked into the bottle. The flow of liquid is immediately checked if air is allowed to enter the bottle by opening the slit in the teat and, provided the delivery end is withdrawn sharply from the liquid, the pipette then remains completely filled to the tip of each capillary. The liquid is delivered by first applying pressure with the teat until the upper capillary is emptied then, with the lower capillary tip touching against the side of the vessel and with the slit of the teat open, the liquid flows out until the meniscus reaches the lower capillary. A further 15 seconds drainage time is allowed after which the residue of liquid filling the capillary is pushed out by gently compressing the teat.

Two variations may be made in the suction apparatus. In place of the slit in the rubber teat, a third tube may be placed in the bung which closes the bottle. This may be closed by a finger when necessary. When it is important that no liquid should be lost in filling the pipette, the rubber teat is replaced by a 1 ml. hypodermic syringe which gives more exact control over the filling of the pipette.

It is difficult to obtain consistent calibration figures for micro-pipettes by the method of weighing the volume of water delivered because evaporation errors are appreciable with small volumes of water. The use of other liquids of lower vapour pressure is not satisfactory since drainage may be materially different from that obtained with dilute aqueous solutions. A pipette of this type is best calibrated by making a number of deliveries

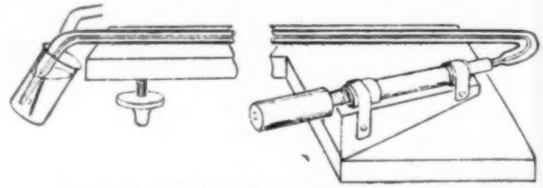


Fig. 2.—A modified form of horizontal burette.

(e.g., 10) of $\frac{N}{2}$ hydrochloric acid into a conical flask then titrating the combined portions with $\frac{N}{10}$ sodium hydroxide using a macro burette. An accurate average value is thus obtained.

A simple horizontal burette suitable for the titration of volumes less than 1 ml. has been previously described.[2] This has been modified and in its present form (Fig. 2) consists of a selected length of manometer tubing, 30–40 cm. in length drawn out to a jet and bent near the jet through rather less than a right angle. The other end is bent as shown in the diagram to make an angle of about 30° with the main burette tube. This end is drawn out to the diameter of the nozzle of a 2 ml. hypodermic syringe to which it is connected by a short length of wax impregnated rubber pressure tubing. The plunger of the syringe is moved by a screw. A trace of vaseline smeared on the plunger eliminates any possible air leakage along the syringe barrel.

With the jet outlet below the surface of a liquid, the burette is filled when the syringe plunger is drawn back. The position of the meniscus is measured against an arbitrary scale of millimetre graph paper and a titration is carried out by slowly pushing the plunger forward, ejecting the reagent from the burette nozzle which is kept beneath the surface of the liquid to eliminate drop errors. The reagent never enters the syringe but makes contact only with the wall of the manometer tube. The details of procedure mentioned in the earlier publication and the use of the burette without calibration hold also for this apparatus. If it is desired to calibrate the burette, this is best done by titrating portions of standard alkali delivered by calibrated micro-pipettes with standard acid in the burette.

It is important to know the variation likely to occur between similar determinations in which a reagent is measured with the pipette and is titrated using a micro burette. Such variation will include errors due to the pipette and burette and the indicator error. Series of titrations were carried out measuring the solution with

2 Holt, P. F., and Callow, H. J., *J. Soc. Chem. Ind.* **61**, (1942), 99.

TABLE I

Pipette	Burette readings (ml.)	Maximum difference (ml.)	Difference %
1	0·4375, 0·4380, 0·4372, 0·4373, 0·4375, 0·4379	0·0008	0·18
2	0·4294, 0·4299, 0·4289, 0·4305, 0·4297, 0·4305	0·0013	0·3

a number of pipettes. With each pipette a portion of a sodium hydroxide solution were transferred to each of six micro beakers, a micro drop of methyl orange was added and titration was carried out with hydrochloric acid of identical strength in the burette. Stirring was effected by bubbling nitrogen from a capillary through the solution. Expressing the maximum variation between any two values in a series of six as a percentage of the titration value, it was found that in no case was the figure higher than 0·5, and that the usual values were 0·2–0·3. Two typical series are given in Table I. It would appear that the variation between titrations is not materially greater than the possible error in reading the burette.

A Simple Inexpensive Ultra-Violet Analytic Lamp

By G. Robinson, A.R.I.C.

The growing use of ultra-violet radiation as an aid to analysis, particularly in the examination of chromatograms increases the need for a simple inexpensive outfit which is flexible ii use, and easy to construct. All the equipment described can be obtained at short delivery and at an outlay of somewhat less than £5.

As a source of low wavelength radiation it was decided to make use of the high-pressure mercury arc, which is reliable and economical in use. This consists of the "Osira" high-pressure mercury vapour lamp marketed by the General Electric Company, and run from a suitable choke and condenser made by the same company. The lamp is designed to work at 200–230 volts at 50 cycles and has a nominal rating of 80 watts.

In its original form the lamp consists of a central small silica discharge tube which provides the light source and an outer frosted bulb which serves to absorb the short wavelength radiation when the lamp is used for ordinary lighting as originally intended. For use as a source of ultra-violet light, this outer bulb is removed, leaving the discharge tube as shown in Fig. 1. Once this has been done, the lamp must never be used without adequate shielding to prevent damage to the eyes of the operator. This is effected by housing the lamp in a small box, in one side of which is a window of Wood's ultra-violet filter glass, which allows only a short-wave band of light to pass out.

Fig. 1.—High-pressure mercury vapour lamp (G.E.C. "Osira") with outer bulb removed, ready for use as a source of ultra violet radiation.

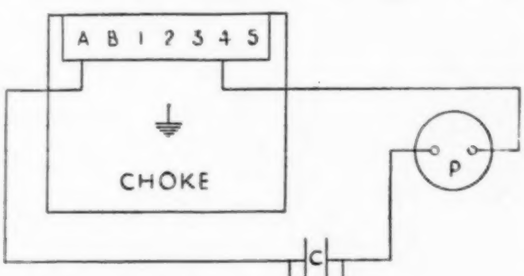
Choice of Suitable Filter

Possibly the most satisfactory filter is the one mentioned above, which has one very outstanding advantage, in that the wave-band passed lies in the range 4,000 A.U. to 3,600 A.U. Light of this wavelength is just below the normally visible spectrum, ane in all cases so far examined, of sufficiently short wavelength to excite fluorescence. Choice of this particular filter was suggested by the fact that this band of radiation was sufficiently long in wavelength to be non-injurious to the eyes and skin of the operator. Most of the harmful biological effects are caused by radiation of about 2,500 A.U. and less, nevertheless, it is suggested that reasonable care be employed by anyone using apparatus of this type, in case of personal susceptibility to short wavelength radiation.

Construction and Wiring

For convenience in handling, the choke and condenser are mounted together on a panel 9 × 6 in., which also carries a two-pin plug socket. The wiring diagram is shown in Fig. 2.

The lamp-holder (a special three-peg type) is mounted centrally on a similar 9 × 6 in. panel. Between the



C = Condenser.
P = 2-pin plug socket.
L = Lead to mains.

Fig. 2.—Wiring diagram for choke panel. Suitable choke tappings for the line voltage used are selected from the chart supplied with the choke. The whole can conveniently be mounted on a panel, 6 × 9 in.

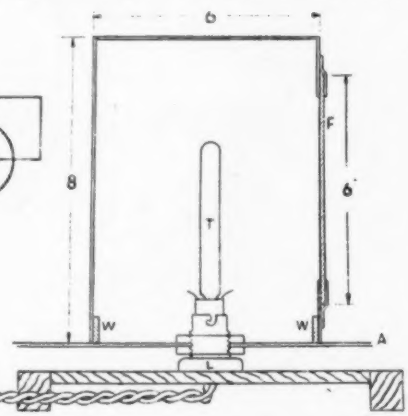


Fig. 3.—Sectional view of Lamp House.
A = Asbestos Sheet. T = Quartz Discharge Tube. L = 3-Peg Lampholder. F = Filter Glass. W = Support Blocks for Light Trap. P = Leads to 2-Pin Plug—(connecting to socket on choke panel—Fig. 2).

two collars of the lamp holder is clamped a 7 in. square sheet of asbestos board about $\frac{1}{8}$ in. thick, to which are fastened four strips of wood about $\frac{1}{2}$ in. high and $\frac{1}{4}$ in. wide, over which slips the metal box ($6 \times 6 \times 8$ in.) containing the filter window. A detailed sketch of this arrangement is shown in Fig. 3. Such a fitting has been found to be adequately light tight and capable of extreme flexibility in use. The whole lamp-house may be swivelled round between the collars of the lamp holder, in order to direct the light in any desired position. Also since any convenient length of flex may be used to make connection to the plug on the choke panel, the heavy and cumbersome part of the equipment can be tucked away under the bench. This leaves only a light and not very bulky lamp house which can easily be clamped at any suitable angle in an ordinary laboratory, retort stand and clamp and moved around with great freedom.

The above is a description of the lamp designed by the author, originally for examining chromatograms, but it has since found application as a general utility analytic lamp which has more than repaid its initial cost in the year it has been in use. One further useful advantage of the apparatus is the comparatively short time required to attain maximum emission of the ultra-violet light. Usually it is possible to make use of the lamp within ten minutes of switching on, and a further five minutes suffices to reach maximum efficiency.

The Institution of British Foundrymen

THE 45th Annual Conference of the above Institute will be held in London from June 8th to 11th, 1948, arranged by the London Branch. A very full programme has been prepared. Following the normal business meeting Mr. R. B. Templeton will give his Presidential address ; later Dr. H. Schwartz will deliver the Edward Williams Lecture ; his subject is "Some Solved and Unsolved Problems in the Metallurgy of Blackheart Malleable." Some seventeen papers will be presented for discussion at special technical sessions and arrangements are made for visits to neighbouring works. A special Ladies' Programme is arranged. The Annual Dinner, followed by dancing, on June 9th, will be held at the Cafe Royal, Regent Street, W.1.

Refresher Course on Cast Iron

THE first post-war Refresher course held by the British Cast Iron Research Association, took place at Ashorne Hill near Leamington Spa, by courtesy of the British Iron and Steel Federation, from 14th–17th April. More than 200 representatives of member-firms, together with students of the National Foundry College and members of the Association's staff, attended the Course, and unfortunately, owing to the number of applications received, it was not possible to accommodate all those who wished to be present. The visitors were welcomed on behalf of the Council by the President of the Association, Dr. Harold Hartley, and more than 20 lectures were given by the staff and by Mr. J. W. Gardom, Mr. L. W. Bolton and Mr. A. E. Probst.

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